No. 2643 VOLUME 76 FRIDAY 6 NOVEMBER 1959

FLIGHT

AIRCRAFT, SPACECRAFT, MISSILES

Official Organ of the Royal Aero Club First Aeronautical Weekly in the World Founded 1909

Editor-in-Chief
MAURICE A. SMITH D.F.C.

Editor
H. F. KING M.B.E.

Technical Editor
W. T. GUNSTON

Production Editor
ROY CASEY

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Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1; telephone Waterloo 3333. Telegrams Flightpres Sedist London. Annual subscriptions: Home £4 15s, Overseas £5. Canada and U.S.A. $15.00. Second Class Mail privileges authorized at New York, N.Y.

Branch Offices Coventry: 8-10 Corporation Street; telephone Coventry 25210. Birmingham: King Edward House, New Street, 2; telephone Midland 7191. Manchester: 260 Deansgate, 3; telephone Blackfriars 4412 or Deansgate 3595. Glasgow: 26B Renfield Street, C.2; telephone Central 1265.
New York, N.Y.: Thomas Skinner & Co. (Publishers) Ltd., 111 Broadway, 6; telephone Digby 9-1197.

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Who Shall Pay?

IN its last-but-one report and accounts (for 1957-58) B.O.A.C. "carried forward for future amortization" a sum of nearly £4½ million incurred in the pre-operational development of Britannias, Comets and DC-7Cs. This, of course, was a perfectly reasonable thing to do: it was expenditure which should fairly be charged against future operations. But in its latest report and accounts B.O.A.C. "have seen fit" to *write off* £5m development expenditure. This is not charged against current operations: it appears in the Corporation's accumulated deficit as a capital loss. The year's operating loss thus appears to Parliament and the public to be £5m less serious than it really is. Here, it seems, something is amiss, for expenditure carried forward cannot suddenly be swept under the carpet of "accumulated deficit" without being shown as an operating loss in the year concerned. This is enlarged upon in our second analysis of the report, on page 488.

Of course, B.O.A.C. strongly believe that their development costs should be paid for by the Government, and Sir Gerard d'Erlanger was encouraged in his decision to write off the £5m by the recent Select Committee's comment that aircraft development costs appeared to fall too heavily on the Corporations. But the Select Committee based its view on the fallacy that "American airline operators have the advantage of having development flying done for them by the Services." This is partly true of the Boeing 707. It is most definitely not true of the Douglas DC-8, the Lockheed Electra or the Fairchild Friendship, and it will not be true of the Convair 880 or of the Convair 600. The American airlines are footing the development bills for all these new transports unaided.

B.O.A.C.'s Britannia development costs were indeed exorbitant. But Government assistance must not be granted solely on the evidence of fallacious Select Committee comparisons with the American airline industry.

An Army Helicopter Corps?

IT was ironic that in the recent Army air mobility exercise Red Banner the only Service helicopters carrying a worthwhile load—3,000 lb—belonged to the U.S.A.F. In an exercise which was described as "experimental, not to be taken to represent official policy" the best that combined Army/R.A.F. resources could do was to put up Whirlwinds and Sycamores—lifting no more than 1,000 lb apiece—and a few Skeeters for carrying senior officers about. It was as if we had only just heard (officially) of helicopters and were trying them out on a small scale; whereas this sort of "experimenting" should have been done ten years ago, so that parachute troops—normally too far ahead to be accessible by road—could automatically be backed by helicopters able both to carry troops and bring up supplies. That is a concept of war dating from 1939-45; and our helicopter manufacturers are well able to supply the required hardware. Both the Bristol 192 and Westland Westminster participated in Red Banner, though only as visitors. If the Army's air mobility exercises (two more of which are envisaged, one in Northern Ireland in December and another overseas next year) are really to mean anything, it is time bigger helicopters were put into uniform.

Who is to fly them—the Army or the R.A.F.?—is a question for the new Minister of Defence or the Chief of the Defence Staff. It would appear desirable to form an Army Helicopter Corps, which would recruit its first pilots from either Army or R.A.F. volunteers. This Corps would operate in the close tactical support rôle, as was demonstrated in Red Banner, and could be equipped with helicopters from Wessex size upwards.

AERIAL TRANSPORTERS: Left, a Sikorsky S-60 with an experimental 20-passenger "people pod," claimed to avoid the usual vibration. Right, with the Westland Westminster "crane," is a Burmese ministerial delegation. L. to r., Harald Penrose, Westland sales manager; Mr. Soo Khun Sam; the Hon. Soo Wunna; Mr. D. C. Collins, deputy managing director; Mr. Saw Ohn Tin; and Mr. W. H. Sear, chief test pilot

FROM ALL QUARTERS

Blackburn Chairman Resigns

IT is announced as we go to press that Mr. Eric Turner is relinquishing his appointment at the end of this year as chairman and managing director of the Blackburn Group Ltd. Mr. Arthur Jopling will become chairman of the Group and Mr. N. E. Rowe and Capt. E. D. G. Lewin joint managing directors of its principal subsidiary, Blackburn Aircraft Ltd. Mr. Turner, who is to become deputy chairman and chief executive of the B.S.A. Co. Ltd., will remain a member of the Blackburn board.

P.1127 and H.P.115

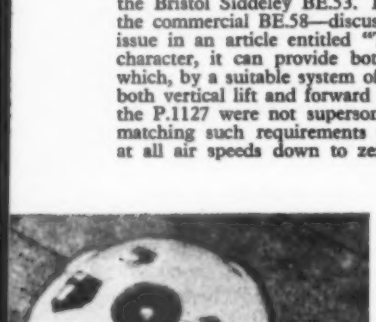
PERMISSION has now been granted for us to make further reference to two new British aeroplanes of exceptional interest. Since January it has been known that Hawker Aircraft are engaged in the development of a VTO close-support fighter designated P.1127, and powered by a "special Bristol engine." It is now possible to confirm our unofficial assumption that this engine is the Bristol Siddeley BE.53. Essentially the BE.53 is similar to the commercial BE.58—discussed at some length in last week's issue in an article entitled "Turbofans." Owing to its unique character, it can provide both hot and cold propulsive flows which, by a suitable system of valving, may be made to provide both vertical lift and forward thrust. It would be remarkable if the P.1127 were not supersonic, and the problems involved in matching such requirements with proper stability and control at all air speeds down to zero, are problems which no other manufacturer has had to meet. It may not yet be said whether the P.1127 has one or two engines; the BE.58 has a maximum sea-level rating of 14,500 lb, but the military BE.53 could very well incorporate afterburning in the cold flow to provide substantially greater output during the vertical take-off.

In *Flight* for October 2 we reported the announcement made by a London daily newspaper to the effect that "a wooden airplane is being built for the Ministry of Supply to help in the investigation of the problems of flying supersonic airliners. The aircraft is being built by Handley Page and is expected to fly next summer." It is now permissible to confirm this statement and give the designation of the aircraft as H.P.115. In the official announcement the machine is described as "a delta research aircraft" and the powerplant as one Bristol Siddeley Viper turbojet.

Keeping Up Sales

BRITISH aviation exports for the first nine months of this year, amounting to £121,294,252, were seven per cent up on the equivalent figure for 1958. The current nine months' total exceeded all the preceding annual ones except that for last year and represents an annual rate of more than £161m (compared with the 1958 record figure of £154m), which is equivalent of £3.1m a week, compared with last year's weekly earnings of £2.9m.

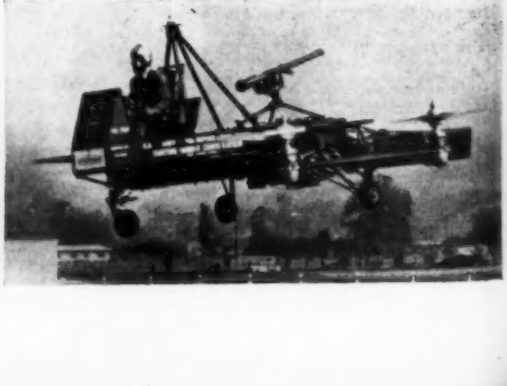
The September exports total, £9,646,677, was about £350,000 more than the September figure last year and sales details were: aircraft and parts, £4,661,961; aero-engines and parts, £4,427,613; electrical equipment, £344,034; aeronautical instruments, £156,846; tyres, £56,223.

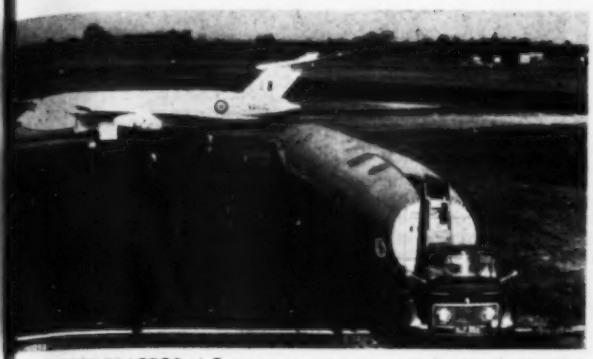


SAUCERS AND PLATFORMS. Left, a "sneak shot" of the Avro Aircraft Avrocar, recently reported to have made a successful tethered flight. At lower left is another air rider (built by National Research Associates), and next is a third, by Mr. W. H. Bertelson. Last is Curtiss-Wright's new aerial platform, the VZ-7AP, designed to fill the gap between the army jeep and the reconnaissance helicopter

Latest From France

AT Melun Villaroche last Friday the Dassault Mirage IIIB two-seater made its first flight, piloted by Cmdt. Bigand. Other Mirages have been flying at Istres with external tanks and bombs. Additional news from France is that Bernard Witt made the first flight of the Bréguet Choucas two-seat sailplane from Toulouse Blagnac on October 26; that two prototype and two production Potez-Air Fouga Zéphyr naval trainers have now been delivered to the French fleet air arm, the prototypes having flown more than 630 hr each; and that a Nord 1100 has flown at Bordeaux, powered by a Turboméca Astazou and Ratier-Figeac propeller installed by SFERMA. This turboprop (and later the Bastan) is to have a new electronic control system.





VICTOR TRACTOR: A Commer ten-ton tractor unit leaving the Handley Page airfield at Radlett with the second prototype Victor fuselage. A special rear bogie is attached to the fuselage itself

RECORD-BREAKER: Jim Mollison, whose death is recorded on this page, with the Gipsy Moth in which he flew from Australia to England to set up the first of his many long-distance records

Jim Mollison

AN adventurous spirit, exceptional powers of endurance and first-class navigating ability marked the flying career of James Allan Mollison, M.B.E., F.R.G.S., A.F.R.Ae.S., whose record-breaking flights made him an outstanding aviation figure in the thirties and whose death last Friday at the age of 54 we record with great regret.

Mollison became famous almost overnight when in 1931 he flew from Australia to England in a de Havilland Gipsy Moth in 8 days 19 hr 25 min, more than two days under the previous record—an achievement which this journal ascribed to the facts that his navigation was good, that the Gipsy engine gave no cause for anxiety and that the pilot went practically without sleep and did a good deal of night-flying. Jim Mollison had gone out to Australia in 1928, after serving in the R.A.F. on a short-service commission, and was first a flying instructor and subsequently with Eyre Peninsular Airways and Australian National Airways. It was in Australia that he met the famous woman pilot Amy Johnson, who became his first wife.

After his Australia - U.K. flight Mollison went on setting up record after record: in 1932, from Lympne to Cape Town in 4 days 17 hr 19 min in a Puss Moth, following a Western route over the Sahara and covering much of that part of his journey by night; in the same year, the first solo crossing of the North Atlantic from East to West, taking off from Ireland and landing in New Brunswick after 30 hr 15 min in the air; in 1933, yet again in a Puss Moth, the first East-West solo crossing of the South Atlantic; and in the same year the first direct flight from the U.K. to the U.S., from Pendine Sands to Bridgeport in Connecticut. This flight, made in a D.H. Dragon with Mrs. Mollison (the former Amy Johnson), was also the first husband-and-wife Atlantic crossing. They also flew together in one of the three D.H. Comets entered for the MacRobertson Trophy race from England to Australia in 1934. They were in the lead to Karachi, having reached India in a day, but had to withdraw at Allahabad owing to mechanical trouble.

Mollison gave up flying before the last war but when it came joined the A.T.A., in which he flew most types of Service aircraft, being made an M.B.E. on retiring in 1945 as a flight-captain. He published an autobiography, called *Death Cometh Soon or Late*.

Institute of Navigation President

NEW president of the Institute of Navigation, W/C. E. W. Anderson, O.B.E., D.F.C., A.F.C., F.I.N., F.R.Met.S., was a founder-member of the Institute and has just completed two years as vice-president. His election took place at the Institute's annual general meeting, with Prince Philip in the chair. W/C. Anderson, well known for his writing on air navigation and his papers on navigation generally, is project manager at the Bracknell Division of the Sperry Gyroscope Co. Ltd. He joined Sperry three years ago after distinguished service in the R.A.F., as a navigator and staff officer with Bomber Command during the war and later as a polar navigation specialist. In 1953 he navigated the first aircraft—a Canberra—to enter a radioactive cloud.

W/C. Anderson

IN BRIEF

Further to the brief, but inaccurate, report by a London newspaper regarding co-operation between Rolls-Royce and M.A.N., it can be said that this work concerns a small jet engine of unusual design and construction the development of which was begun by the British firm.

A new company, Svensk-Engelsk Aero-Service A.B., has been formed in Stockholm as a subsidiary of the Bristol Aeroplane Co. Ltd. It is to act as a service liaison link between Bristol and the Royal Swedish Air Board, who last year placed an order for the Bloodhound SAGW system.

Three Westland Whirlwinds flown by crews of Bristow Helicopters Ltd. left Battersea Heliport last Saturday morning for Kuwait and Das Island in the Persian Gulf, making what is said to be the longest flight ever undertaken by British-built helicopters. Two of the Whirlwinds are to be based on Das under contract to British Petroleum Ltd. and the third is being maintained and operated by Bristow for Sheikh Abdulla Mubarak, deputy ruler of Kuwait and civil aviation president.

An R.A.A.F. team consisting of A. Cdre. D. W. Kingwell, R.A.A.F. representative in the United Kingdom, and S/L. L. Hawes, a member of his staff, have visited Macchi in Italy to inspect and fly the MB.326 jet trainer. Macchi report that they were impressed by their experience. This was a routine inspection of a new aircraft, part of a general investigation of jet trainers. A Hunting Jet Provost is at present being evaluated for pilot training in Australia.

In recent months the British Ministries of Defence and Supply, in conjunction with the War Office, have "re-thought" the anti-tank missile picture. As a result the weapon system under development by Fairey Aviation's Weapon Division at Heston has been cancelled, although it met all requirements as originally stated. In its place the British Army will have a number of Malkaras (p. 520) and Fairey have received a contract for work on a different missile. (The London *Daily Express* name the original Fairey weapon system Orange William, the third unofficial disclosure of a missile code-name in five weeks.)

Mr. E. T. Jones, Deputy Controller (Overseas Affairs), Ministry of Aviation, was elected deputy chairman of AGARD (Advisory Group for Aeronautical Research and Development) at its ninth annual general assembly, held recently at Aachen, Germany. He is the first holder of that position.

The first production Series 3 Scottish Aviation Twin Pioneer was recently flown out to the Iraq Petroleum Company's base at Kirkuk in Iraq, where it will be used to carry executives and equipment between oil sites. The company and its associates have for the past two years operated two Series 1 Twin Pioneers in the Basrah and Trucial Oman areas.

After serving as parachute representative on the Aviation Committee of the Royal Aero Club since January 1957, and as chairman of the club's parachuting committee since its formation in February this year, Maj. T. W. Willans has resigned from the latter appointment. He is succeeded by Mike Reilly, a founder-member and instructor of the Ripcord Club.

Trophies and diplomas were presented by Mr. Donald Campbell at the annual awards day of the College of Aeronautics and Automobile Engineering, Chelsea, on November 2. In his opening address, Lord Sempill announced that the new president of the College, the Duke of Edinburgh, began his period of office on that day. The Principal, Mr. J. A. C. Williams, reported the highest number of students since the foundation of the College.

A painting by the Cheltenham artist Mr. James Martin depicting the Gloster E.28/39 under construction was unveiled at the Regent Motors (Cheltenham) Ltd. showrooms on October 29 by Mr. H. Burroughes, chairman of the Gloster Aircraft Co. Ltd. The E.28/39, powered by the Whittle W.1X jet engine, was constructed in a closely guarded section of the Regent Motors' premises during 1940-41 before being removed by road for flying trials. The designer of the aircraft, Mr. George Carter, was present at the Cheltenham ceremony.

Flying the Hard Way

ROYAL AERONAUTICAL SOCIETY MUSCLES-IN ON MANPOWERED FLIGHT

FLAPPING-WING flight is no longer strictly for the birds. This was the vow taken in the library of the Royal Aeronautical Society on Friday last, when the Society bestowed respectability on the advocates of manpowered flight by accepting them as a fully fledged R.Ae.S. Group. Not that ornithopters were deemed to be the only means of achieving this, the ultimate in do-it-yourself flying, for there were many fixed-wing enthusiasts present. But whatever the exact shape of the device, the message came over loud and clear, if a little breathless—every man his own aero-engine.

The meeting began with outlines of particular aspects of the subject by five variously qualified experts. Chairman for the evening was Mr. Peter Masefield, President of the Society, who first introduced Mr. H. B. Irving to describe how the Manpowered Aircraft Group of the Society had come into being.

It all began, Mr. Irving said, at an informal meeting at the College of Aeronautics, Cranfield, on January 10, 1957. This was the birth of the Manpowered Aircraft Committee, which now formed the steering committee of the new group. The committee had been in touch with similarly minded individuals and groups in a number of countries and had discovered, for instance, that the Russians were concentrating exclusively on ornithopters, to which end they had recently held a five-day, 150-delegate conference on flapping-wing flight.

The next speaker was Mr. J. L. Nayler, who gave a brief historical outline of attempts at manpowered flight and then discussed some aspects of bird flight. Among the relevant points from this second section were the facts that a pigeon uses five times as much power to take-off as to maintain level flight; and that, while the muscle content of a bird amounts to half its total weight, that of a man is only one-fifth.

Man's efficiency, and inefficiency, as a power source was next described by Dr. D. R. Wilkie of University College, London. This power came ultimately from the oxidation of carbohydrate foodstuffs, he pointed out, and so was ultimately limited by the body's ability to take in and process oxygen. For short periods, however, the muscular power output could be much greater than the simultaneous oxygen intake. Typical figures (for champion athletes) showed that 3-5 h.p. could be produced for a period of a few seconds; 1 h.p. for about one minute; 0.7 h.p. for about three minutes; and about 0.5 h.p. as a normal continuous level for five minutes or longer.

This long-duration power output depended solely on the oxygen supply, Dr. Wilkie emphasized. A cycling motion was probably the best way of applying manpower: pedal cycling could absorb all the oxygen-energy available, and gearing could be very efficient. For short-period efforts, rowing action was uneconomical. All in all, it appeared that man was not a particularly good aero-engine, but he could probably fly for a short period and possibly longer.

Aerodynamic Problems

The aerodynamics of manpowered aircraft was next on the agenda. The speaker was Terence Nonweiler, senior lecturer in aeronautical engineering at Queen's University, Belfast, who concentrated on his own two-man fixed-wing design. Model tests had shown that a one-per-cent increase in all-up weight would result in a five-per cent drop in flight duration; a one-per-cent change in structure weight meant two per cent in duration; while a one-per-cent change in drag implied slightly over three per cent in duration. This means that cutting down drag would pay good dividends—more so, in fact, than in a conventional aircraft.

"An honest aerodynamicist must admit that he knows next to nothing about flapping-wing flight." the speaker said, turning away from fixed-wing aspects. As Mr. Nonweiler is well-known to be a scrupulously honest aerodynamicist, it was no surprise that he soon turned back again to his own fixed-wing design, to report that it was currently the subject of slow (80 man-hours per week) but sure study by himself and a number of his degree students at Queen's.

The final speaker from the platform was Mr. B. S. Shenstone, chief engineer of British European Airways, who spoke on the engineering aspects of the manpowered-aircraft problem, illustrating his talk with slides of the Haessler-Villinger, Bossi-Bonomi, Filter, Perkins and Hartman aircraft and designs by Nonweiler, Shenstone and Wilkie. The pre-war Haessler-Villinger, which had flown for distances of some 200 yd in 20 sec on about 0.8 h.p., weighed 100 lb empty.

On the subject of structures, Mr. Shenstone's paper included the following points:

"The main structural problem is the wing. It must be as light as possible, but must retain its shape during take-off and in flight to such a degree that the requisite smoothness and waviness conditions are preserved. In spite of being light, it must be sufficiently stiff to enable the aircraft to be controlled in bank by whatever aerodynamic means are proposed. The order of size is something like a span of 50ft, and an aspect ratio of the order of 15, which gives a wing area of between 150 and 200 sq ft for a two-seater. Such a wing may be braced or it may be cantilever. The braced wing may possibly be lighter but it will have more drag. . . .

"There are a number of structural materials that may be used. Perhaps the most straightforward material is wood, which would mean essentially spruce and plywood. The difficulty here is that the loads of manpowered aircraft (ultimate load factor about 2.5) are very small indeed and so the scantlings or the dimensions of the various pieces of structure would tend to be very small indeed. For instance, if a single-spar wing were to be used with a torsion-resisting nose, the structure at the rear part of the wing, which carries only the local loads and leads them to the spar, could be so flimsy that it would be difficult to build, and even the lightest of fabric covering might distort the structure. . . ."

Apart from the wing the main structure consisted of the fuselage which, Mr. Shenstone suggested, might be considered as a place to sit and work, a fairing for the workers, a base for the attachment of the propeller and a means of connecting the wing to the tail. The shape and size of the fuselage was intimately connected with the type of drive used, and this again was linked closely with the aerodynamics. For instance, if it were found that a very short compact drive was much more efficient mechanically than a longer drive shaft, it might be necessary to use a tailless or tail-first arrangement.

Design of the Drive

The second major problem was the design of the drive. In Mr. Shenstone's opinion, initial advantage should be taken of highly developed equipment in other fields—such as the racing bicycle. This had been developed over the last 50-60 years to a high degree of perfection.

"With two men we have the problem of three sets of pedals, the pilot using his legs and the other man using his arms on one set of pedals and his legs on the other. These must be linked together to one shaft. Whether the chain with its zero slip, or a belt or cord with its considerable slip but lighter weight, is the better is not possible to decide in a general fashion. . . .

One of the first questions to be posed in the general discussion which followed the five main papers, and one which recurred later, was the problem of ethics. Should we strive for one-hundred-per-cent manpowered flight, with nothing up the sleeve, no artificial aid, and positively no deception? Or could we store our energy for take-off, use hill-lift, and jump off cliffs? One speaker from the floor suggested throwing ethics overboard and ourselves over cliffs, but the quintet of experts thought this wasn't really playing the game, chaps; it really ought to be all or nothing at all.

Another question had the same theme—how about using oxygen? Dr. Wilkie agreed that this could boost one's continuous power output. Were big men better than little men, enginewise? Dr. Wilkie replied that big, muscular types would certainly produce more take-off than lightweights, but not necessarily when flying straight and level and running on oxygen alone, so to speak. Several ornithopterists also contributed to the discussion, as did a white-haired gentleman from the back row who claimed that he could harness wind-power not only for engineless flight in light aircraft but also to drive Britannias at 600 m.p.h.

The managing director of Bristol Aircraft, Mr. Peter Masefield, took this last item of news calmly as he rose to give his final summing-up. This was only the beginning, he said, of what was essentially a sporting endeavour. A joint group project should be started, possibly with the support of both the Society and the Royal Aero Club (Mr. Masefield wears two highly relevant hats in that he is chairman of the R.Ae.C. aviation committee as well as R.Ae.S. President). He personally favoured a contest for the first circular mile covered in free manpowered flight. This would indicate the ability to control the aircraft as well as simply to maintain flight, and would provide a good primary target at which to aim. If there was any big money around, it should be used not as a large prize but to sponsor "the best possible manpowered aircraft that money can buy and brainpower can devise."

The inaugural meeting of the Group had been extremely well-attended, doubtless due in large measure to the awakening of interest in the subject following the recent news of the aircraft of Emiel Hartman and Daniel Perkins. Both Mr. Hartman and Mr. Perkins were present among the audience at the meeting, but both chose to remain silent during the discussion. K.T.O.

SERVICE AVIATION

Royal Air Forces and Naval Flying News

Air Chief Marshal Sir Hubert Patch, who recently assumed the post of C-in-C. British Forces Arabian Peninsula, being greeted by the Sultan of Lahej after a parade of the Federal National Guard in his honour

New World Visit

ON Sunday the C.A.S., Marshal of the R.A.F. Sir Dermot Boyle, left for the United States by Comet 2 of No. 216 Sqn. He is having discussions at the Pentagon, touring some U.S.A.F. installations, and seeing R.A.F. Thor crews in training at Vandenburg A.F.B. in California. It will be recalled that the Chief of Staff of the U.S.A.F., Gen. Thomas D. White, visited the U.K. earlier this year.

Next Thursday the C.A.S. flies to Canada, where he will have meetings with the Minister of Defence, Maj-Gen. the Hon. George R. Perks, and the chairman of the Canadian Chiefs of Staff, Gen. Charles Foulkes, and talks with the Canadian Air Council. Sir Dermot is due to leave for home on November 14.

Air Council and AAFCE Posts

THERE are to be moves between Fontainebleau and London early next year under two appointments announced by Air Ministry last week. Air Marshal Sir Walter Merton, K.C.B., O.B.E., a Canadian, is relinquishing the post of Chief of Staff at Allied Air Forces Central Europe to join the Air Council from April 8 as Air Member for Supply and Organization; and he is being succeeded at AAFCE headquarters at Fontainebleau from February 9 by A.V-M. D. G. Morris, C.B., C.B.E., D.S.O., D.F.C., a South African, who will become an acting air marshal in his new post.

Air Marshal Merton was made AAFCE Chief of Staff in February this year, having been A.O.A. at Bomber Command since September 1956. Prior to that he was Chief of the Air Staff, Royal New Zealand Air Force, for two-and-a-half years. In his new Air Council appointment he will succeed Air Chief Marshal Sir Walter L. Dawson, who is retiring from the Royal Air Force.

A.V-M. Morris's present post is that of A.C.A.S. (Air Defence), which he took up when it was created in April 1957 to control the integration of guided weapons and their associated equipment into the U.K. air defence system. He had previously been S.A.S.O. at 2nd A.T.A.F. headquarters, Germany, from January 1955.

Off to Antarctica

AT least five members of the R.A.F. are sure to see plenty of snow this winter, for they are spending it in the Antarctic with the Falkland Islands Dependencies Survey, forming a detachment to provide aerial support with an Otter and a Beaver. The leader, F/L. D. English, sails from Southampton in December aboard the Danish vessel *Kista Dan*. His fellow-pilot, F/L. R. A. Lord, left in the research ship *John Biscoe* on October 19 accompanied by C/Tech. P. Bates, an airframe fitter. Two other N.C.O.s are travelling with F/L. English: F/Sgt. T. Sumner, an aircraft fitter, and Cpl/Tech. M. Horton, an air radio fitter. When F/L. Lord and C/Tech. Bates reach Deception Island (in about three weeks' time) their first task will be to prepare a short airstrip for the Otter, which will be assembled there. Both aircraft are being picked up by F/L. English at Montevideo, Uruguay, and the Beaver is to be uncrated on board ship and assembled either there or on the ice edge.

Oman Awards

TEN awards to R.A.F. personnel for gallantry and devotion to duty in Oman air operations were announced last week. They are as follows:—

Bar to the D.F.C.: W/C. J. C. Graham, D.F.C.

D.F.C.: W/C. B. W. Parsons, A.F.C.; P/O. J. H. Martin.

D.F.M.: F/Sgt. P. Boniface, A.F.M.

Mentions in Despatches: S/L. T. R. Holland; F/L.s J. H. Besant, D. S. Burden, K. D. Jefferies and R. R. Kennedy; and F/O. C. F. White.

Unified Singapore Command?

A REPORT in a Singapore newspaper, the *Sunday Mail*, said recently that the three British defence services in Singapore might be brought under a single command, possibly under Air Chief Marshal the Earl of Bandon, the present C-in-C. Far East Air Force. It added that big changes were planned in the administration, function and strength of the three armed services based in Singapore.

Thorney Island Story

THIS year sees the 21st anniversary of Thorney Island as an R.A.F. station, and to mark this a record of its history is being compiled. An appeal has been made for relevant material, especially from those who served there during the war years, and anyone able to contribute should communicate with F/O. D. Barnes, R.A.F. Thorney Island, Emsworth, Hants.

IN BRIEF

R.A.F. Waterbeach (Fighter Command) has won the Jolliffe Trophy, awarded annually for the most attractive and efficiently run dining-hall on a home R.A.F. station, for the second year in succession. It is being presented today (November 6) by Air Marshal Sir Arthur McDonald, Air Member for Personnel.

* * *

The foundation stone of a new headquarters building for the Meteorological Office was laid at Bracknell, Berks, on October 28 by Sir Cyril Hinshelwood, president of the Royal Society. The premises are expected to be in use by 1961.

* * *

A Rollason Turbulent has been lent to the Central Flying School at the request of the Commandant, A. Cdre. J. N. H. Whitworth, for the recreational use of pilots there. After three weeks at Little Rissington the Turbulent is going to R.A.F. Wattisham.

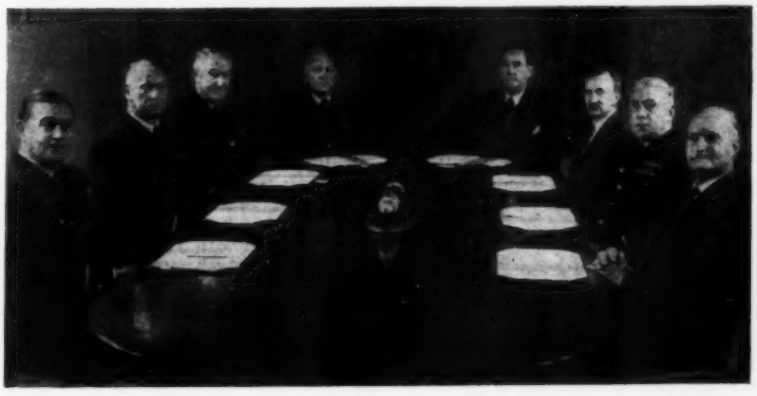
* * *

The Brooke-Popham Memorial Trophy has been won for 1959 by W/C. D. W. Densham. Commemorating the late Air Chief Marshal Sir Robert Brooke-Popham, it is awarded for competition among officers on the R.A.F. Staff College course for the best essay on a selected subject.

* * *

The R.A.F. Central Band left Lyneham on Wednesday last week for Salisbury, Southern Rhodesia, aboard a Britannia of No. 99 Sqn. on a training flight. After giving concerts in Rhodesia, Kenya and Mauritius the band was due to return to the U.K. yesterday (November 5), having flown 14,000 miles in nine days.

The R.A.A.F. Air Board in session at Melbourne before A.H.Q. moved to Canberra. From left to right: A.V-M. A. M. Murdoch, D.C.A.S. (shortly taking over as Head of the Australian Joint Services' Staff in London, and succeeded as D.C.A.S. by A.V-M. I. D. McLachlan); A.V-M. A. L. Walters, A.M.P. (now A.O.C. Support Command and succeeded by A. Cdre. F. Headlam as Acting A.M.P.); A.V-M. E. C. Wackett, Air Member for Technical Services; Air Marshal Sir Frederick Scherger, C.A.S.; the Hon. F. M. Osborne, Air Minister; Mr. A. B. McFarlane, Secretary, Department of Air; A.V-M. H. G. Acton, Air Member for Supply and Equipment; and Mr. F. Mulrooney, assistant secretary



AIR COMMERCE

B.O.A.C.'s 1958-59 Report: a Postscript

AN airline should not be judged solely on its annual report: some of the most efficient airlines present the skimpiest reports. This is the perspective in which to read this "Flight" review of B.O.A.C.'s recently published Report and Accounts (a preliminary appraisal of which appeared last week). But it should be possible, as B.E.A.'s example suggests, for a concern having public accountability to produce for Parliament and the public a really thorough report of its affairs.

ON any realistic reckoning, B.O.A.C. last year lost almost £12 million. In public the Corporation considers that the loss is only £5 million, and that the balance relates to past years. Yet over the past few years B.O.A.C. have been understating losses, or exaggerating profits, by (1) shuffling development costs into such future years as the aircraft concerned would be fully operational, and by (2) charging what appear to have been inadequate amounts for obsolescence. Now that these chickens must come home to roost the Corporation says, in effect: "We won't set them against this year as they relate to past years."

The £5 million development costs (see page 483) could have been spread over the Britannias' and Comets' first five years in operation. But as a policy decision, to help their airline get back into the black as soon as possible, the Board have now written the entire cost off as a capital loss. In the case of obsolescence charges, the Corporation agreed with the Ministry of Transport a few years ago that they were failing to depreciate their aircraft fast enough. Although B.O.A.C. reduced the depreciation period to seven years, they apparently misjudged the residual value, for last year they suffered a capital loss of over £1 million on the disposal of aircraft. The Corporation admits that over this current year it is also likely to show a capital loss on this item; this is an indirect way of saying that the aircraft are still being under-depreciated.

An unwillingness to face the unpalatable facts in print is apparent in the pages of the report. For instance, B.O.A.C.'s rate of growth last year of 9 per cent is compared with "an average of 5 per cent for all major airlines." This comparison was intended to show that the Corporation's rate of growth was above average. Yet the fact is that I.A.T.A. airlines as a whole—and they are the only reasonable yardstick for such a comparison—increased their business by 9 per cent, while the volume of international traffic increased by 15 per cent (17 per cent if B.O.A.C. is excluded). Comparing like with like, B.O.A.C. were behind last year. It was perhaps this that led the report later to say that the Corporation's share of international traffic for last year was "not yet available." The I.C.A.O. headquarters in Montreal could have provided the figures to show that B.O.A.C.'s share had dropped from 8.2 per cent to a provisional 7.5 per cent—the biggest drop since the Comet 1 disasters.

Layout of the Accounts

Turning from the report to the accounts, two aspects in particular call for comment. Continued non-standardization of the layout makes it virtually impossible to compare the accounts year by year. The Corporation's big brother, the British Transport Commission, has shown that unpleasant facts can often be concealed merely by changing the layout of the accounts. Although many of the changes in B.O.A.C.'s accounts certainly conform to better accounting practice, one change in the latest accounts certainly does not do so: to switch a *capital* item, in this case capital reserves, from the left-hand side of the balance sheet and to show it as a deduction from a *revenue* item on the right-hand side of the account (namely, accumulated losses on the profit and loss account), is a procedure that few private companies would adopt.

Undoubtedly the most unsatisfactory changes are to be found on the profit and loss account. For example, a year ago the chairman declared that the Corporation's own operations, before remuneration of capital, showed a profit of £129,122. Now the figure for that same year is given as a loss of £327,902.

Secondly, the section about the associates is disappointing. The Corporation's accountants have gone to some lengths here—following the criticisms of the Select Committee—to improve the record. But the picture remains confusing. What, for instance, is the point of showing for each subsidiary company the revenue and expenditure "attributable" to B.O.A.C. without explaining how these figures are arrived at? What has happened to the interest due from B.W.I.A. and T.H.Y. on loans of £1.3 million and £1.4 million respectively? What is the item of £852,000 "interest and provisions" against Middle East Airlines when interest could hardly have amounted to more than £100,000?

Attention to detail might have been closer. For example, there are no comparable figures for seat-miles and passenger-miles. This information has to be obtained from M.T.C.A. or I.A.T.A. statistics. There are also anomalies, such as that on Table C-2 on page 47. And to add confusion there are no less than four different values for capacity ton-miles.

This lack of attention to detail is also shown in the "popular" version of the annual report, which is being given away as publicity material. This attractively laid out booklet, in colour, contains an entry to the effect that £5¼ million of B.O.A.C.'s investment in subsidiaries is locked up in "discount and equipment."

But the critic must not, in finding fault, fail to draw attention to one very important improvement in B.O.A.C.'s affairs: costs are once more on the downward trend. Last year showed a cut in unit costs of 6 per cent to almost 36 pence per c.t.m. Mr. Smallpeice reported at a recent news conference that the current figure is down to 35 pence, and by 1961 the level should be about 30 pence. Most of this impending reduction should come from a fall in maintenance costs from 10 to 5½ pence per c.t.m. Last year's reduction was due partly to a cut in maintenance costs and partly to a transfer to turbine fuel. This latter factor, coupled with the Britannia's favourable fuel specifics, led fuel costs to fall from 5.6 to 4.6 pence per c.t.m. (strangely enough, this economy has never been acknowledged in either of the Corporation's last two accounts although it has been a most significant item of saving).

Reduced Insurance Costs

Another item which led to last year's fall in costs was a reduction of £½ million in insurance against passenger claims. Again, no reference is made to this, perhaps because it is unusual for an organization entirely lacking in reserves—indeed, with an accumulated deficit of £15 million—to shoulder so large a share of its insurance risks. A final item which accounted for one-third of the recent cost reduction was the rapid increase of regular contract services for Commonwealth partners. A large part of the costs of these services is borne by the partners. (If B.O.A.C. cared to do all their services under contract to their partners they could show an apparent fall in unit costs to 30 pence per c.t.m. tomorrow!)

Higher utilization will be an important factor in real cost reductions in the years ahead. The Comets, for instance, which a month ago were flying 6½ hours a day, should be doing 10 hours daily by next summer when they have been taken off the North Atlantic routes. Indeed, utilization rates have already started rising sharply since the Comets were put on to the Australian run earlier this month.

Staff productivity, measured in conventional terms, is also planned to increase from 19,000 c.t.m.s. per employee last year to about 35,000 c.t.m.s. in 1960-61. The past ten years have shown a fairly steady increase from 7,000 c.t.m.s. in 1949-50, though this has been entirely due to the use of faster, bigger aircraft. Measured in terms of hours per employee per year—speed and payload being considered as measures of the productivity of aircraft rather than of employees—staff productivity is seen to have remained virtually unchanged over the past ten years.

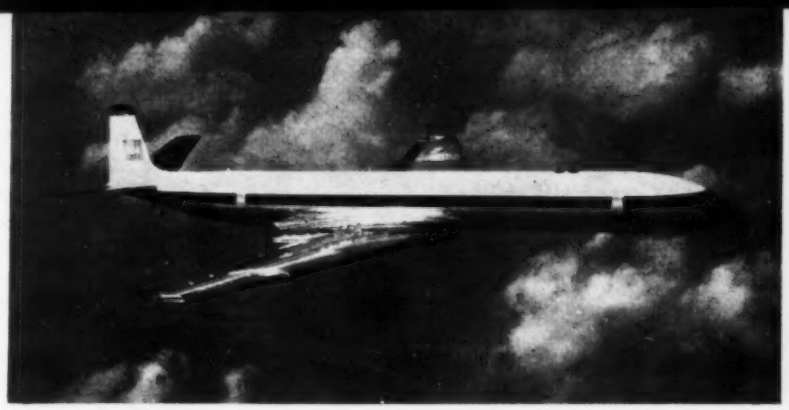
Total staff, which almost reached 20,000 employees a year or two ago, has now dropped below 19,000. Of the original surplus 3,000 engineers, some 1,200 have already gone "through a process of normal and accelerated wastage, supplemented by earlier retirement of a number of more senior staff." Many of the remaining 1,800 engineers are likely to be retained, for Britannia man-hours have proved to be unexpectedly high (40 per cent more than the DC-7C, for instance), and Comet 4 Check Four man-hours have not yet been determined.

Looking further forward, the Corporation expects that capacity will stand at over 600 million ton-miles in 1963-64, an increase of 160 per cent over the present level. Most of this increase will come on the Western routes, which at present account for about one-half of B.O.A.C.'s business. In comparison with four-fold expansion on these services, the Eastern and Southern routes are expected to increase by only 50 and 20 per cent respectively. (This, incidentally, does not say much for the Corporation's belief in the traffic-creating qualities of economy-class fares.)

Although the Corporation's past published forecasts of future growth have proved optimistic, there is no doubt that a sharp increase in capacity, coupled with competitive cost levels, will place B.O.A.C. in a powerful position in the years ahead. Mr. Smallpeice recently described the Corporation as "an active and virile organization all stripped for action and ready for the expansion of British air transport." All being well, B.O.A.C. should be restored to profitability by next summer. It is to be hoped that their results improve as much in presentation as in content.

AIR COMMERCE . . .

B.E.A.'s Comet 4B Plans



ON APRIL 1: JET SERVICE TO ATHENS, ISTANBUL, MOSCOW, MUNICH, ROME, WARSAW

THE official handing over of the first de Havilland Comet 4B to British European Airways is arranged for Monday, November 16. Meanwhile the Corporation is due to accept an advance delivery this week.

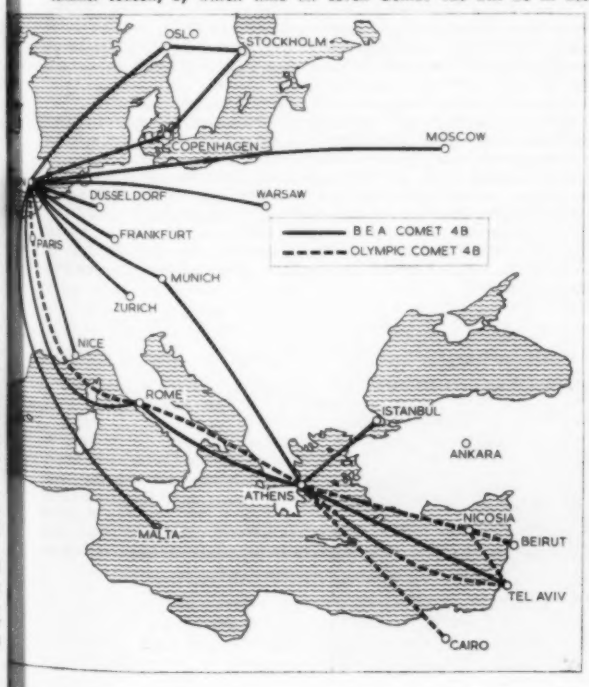
TOMORROW, November 7, B.E.A. are due to take delivery of their first jet airliner, de Havilland Comet 4B G-APMB, the first of a fleet of seven. Like B.O.A.C.'s Comet 4s, deliveries are ahead of the contract schedule; original 4B delivery date was January 1, 1960. Five will have been handed over by April, and all seven by June.

For the next four years, until Comet 4Bs are returned to de Havilland when deliveries of a fleet of 24 "second-generation jet" D.H.121s begin, roughly one quarter of B.E.A.'s capacity will be produced by Comet 4Bs. Utilization is aimed at 2,400 hr per aircraft per year, a work-rate almost equal to the figure (high for a short-haul network) now achieved by the Corporation's Viscounts.

At one stage in B.E.A.'s planning a Comet utilization of 2,800 hr per aircraft was seriously considered, on the basis of six aircraft and no standby. When the "consortium partnership" with Olympic was agreed in July, 1959, and the Greek airline bought two Comet 4Bs and integrated its route pattern with B.E.A.'s (see diagram), it became apparent that the scheduling was too tight to be workable without a standby aircraft. This was the reason for B.E.A.'s purchase in August of a seventh Comet 4B.

At 2,400 hr per year (a rate which will be attained within three months of entry-into-service), the Comets will be providing roughly as many seat-miles per year as a fleet of 25 Viscounts. Upon B.E.A.'s success in selling this capacity, in addition to that of 20 Vanguards, obviously depends their profitability in the first half of the 1960s.

This is how B.E.A.'s jet network will look at the height of the 1960 summer season, by which time all seven Comet 4Bs will be in use



Comet 4B services, operated 86-seat mixed-class (22 first-class four-abreast, 64 tourist-class (five-abreast and 33in pitch) will be introduced as follows:—

April 1 *London - Athens:* This route will be flown by B.E.A. and Olympic as the axis of the "consortium partnership agreement" signed last July by Lord Douglas and Mr. Aristotle Onassis. This agreement resulted in Olympic's purchase of two Comet 4Bs (to be maintained by B.E.A.) and the complete commercial and operational integration of the Olympic and B.E.A. route patterns between Europe and the Middle East. The consortium integrates the schedules of each airline's Comet 4Bs, Viscount 806s (B.E.A.) and DC-6Bs (Olympic), and establishes Athens as a sort of Clapham Junction of the Eastern Mediterranean.

The broad strategy is for two of B.E.A.'s Comet 4Bs and Olympic's two 4Bs to operate on a daily basis into Athens from London, Paris and Rome. From the Greek capital they will fan out to Istanbul, Nicosia, Beirut, Tel Aviv and Cairo. At the same time B.E.A.'s Viscount 806s and Olympic's three DC-6Bs will regularly connect London, Frankfurt, Rome, Milan, Geneva and Zurich with Athens, fanning out thence to the Middle East areas mentioned above, including Ankara.

Athens will thus be the consortium's junction box for connections from eight big European cities to six big Middle East cities, and *vice versa*. Each airline will have greatly enlarged scope for inter-line and interchange opportunities. B.E.A. aim to increase their revenue over these routes in 1960-61 by 30 per cent. Already B.E.A.'s East Mediterranean routes, being long-haul and relatively non-seasonal, are the Corporation's most profitable. Now, with the Athens "booster station" providing more payload to points in the Middle East, these routes should sustain this profitability by providing the traffic for the Comet 4B fleet.

For Olympic the economic advantages of the consortium are a minimum jet fleet, to be maintained by its partner, and the maximum of traffic. It should be noted that the schedules of Cyprus Airways (connecting Nicosia and Athens with Istanbul, Ankara and Beirut) are fully integrated into the B.E.A.-Olympic consortium.

April 1 *London - Moscow:* This service, unlike the present Viscount 806 flights, will be non-stop, and it will be advertised as "Midnight to Moscow." The 3½ hr flight will leave London twice-weekly at midnight, delivering passengers to Moscow—thanks to a three-hour time difference—in time for the day's work. The aircraft will be turned round in 2½ hr, arriving in London also in time for passengers to begin a day's work. It will then be ready to leave at a peak morning hour on another day service to the Continent. Incidental but important considerations behind the Midnight to Moscow schedule are the avoidance of crew transport and hotel expenses in Moscow and, in the winter months, freezing up of the aircraft during a long overnight turn-round.

April 1 *London - Warsaw:* There will be a twice-weekly non-stop flight to the Polish capital, with an overnight turnround. Elapsed time each way will be 2½ hr.

May 1 *London - Copenhagen, and Oslo/Stockholm:* The traffic flows on the U.K. Scandinavian routes have suggested a new pattern for the reciprocal S.A.S. Caravelle and B.E.A. Comet 4B jet services. Since London - Copenhagen traffic volume is about twice that of London - Oslo/Stockholm, the new pattern might be for each airline to fly a daily service to Copenhagen, and to fly alternately a daily service to Oslo and Stockholm. This has been discussed with S.A.S., but it is believed that no agreement has yet been reached due to the effect upon the existing pool agreement of the capacity differences between the Comet and the Caravelle. Plans meanwhile are for a daily flight to Copenhagen, daily to Oslo/Stockholm, with weekend night flights June-September to Stockholm via Copenhagen.

May 1 *London - Nice:* A daily jet flight, the same frequency as Air France's Caravelles already on this route, will bring the Riviera

AIR COMMERCE . . .

B.E.A.'s Comet 4B Plans . . .

within 105 minutes of London. On May 1 also there will be other Comet 4B flights as follows:—

London - Dusseldorf: A daily service has been provisionally planned, and—

London - Malta: A non-stop nightly service is planned. This 1,300 st.m. route is typical of others (e.g. London - Moscow) which the Comet should do more economically than the Viscount because its range and speed enable a quick non-stop return-service to be operated.

July 1 *London - Zurich:* A daily and a nightly service will be introduced on this route. By agreement with Swissair no jet services will be operated between London and Geneva.

July 1 *London - Frankfurt:* A daily service has been provisionally planned.

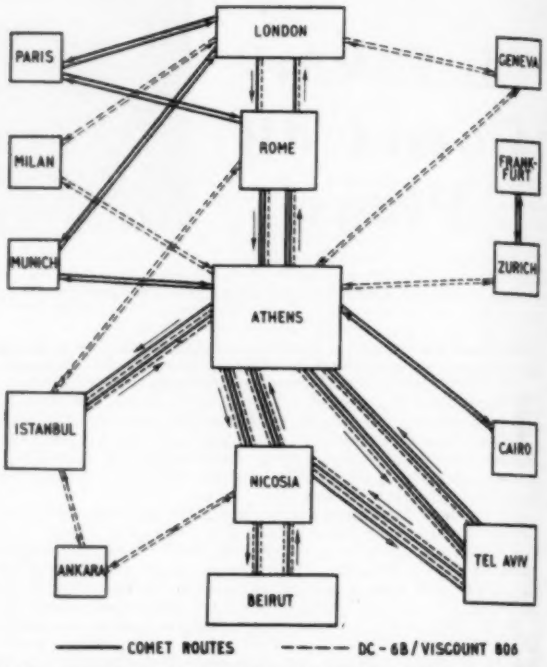
* * *

This programme is an ambitious racing start for a new aircraft, but B.E.A. are confident that it can be achieved. The only concession to the possibility of unexpected snags is that, until July, one aircraft will be kept out of service to provide some slack while experience is gained.

B.E.A.'s Comet Flight will have 30 three-pilot crews, and the Corporation expects to have the crew-training programme completed by July. They have already sought and been extended the fullest co-operation by B.O.A.C. and R.A.F. Transport Command, and B.E.A. pilots have been flying in B.O.A.C. Comet 4s and R.A.F. Comet 2s as supernumerary crews down the line. In addition, B.E.A.'s operations people have drawn fully on the flight-planning, cruise control and general operational procedures developed by these two Comet operators, adapting them to their own more specialized short-haul needs. But B.E.A. will be entirely independent so far as maintenance is concerned: they want to develop their own jet-engineering methods and in any case do not believe that subcontracted maintenance would be economic or practicable in view of the different pattern and tempo of their Comet services. B.E.A. have decided also to be independent so far as simulator-training is concerned, and the Corporation has already installed an Air Trainers Comet 4B flight simulator at its Heston training base.

Before the official inaugural date of April 1, many of B.E.A.'s passengers expecting to fly on, say, a Viscount service to Nice may find themselves on a Comet service instead. This is because B.E.A. will introduce their new jets into service on an *ad hoc* basis prior to the inauguration of general services on April 1, thus giving many Christmas customers a pleasant surprise. J. M. R.

B.E.A.-OLYMPIC INTEGRATED SYSTEM



A diagrammatic illustration of how the two Comet 4B operators will integrate their routes, as discussed in the text

B.E.A. ADVISE ON SLUSH

FOR the past two years at the end of the summer season B.E.A. have issued to their pilots little booklets of reminders about the hazards of winter flying. This year's, called *Winter Pattern 1959*, deals with pre-flight procedures, take-off, climb, cruise, let-down and approach and landing.

In view of the current preoccupation with problems of slush on the runway (see "Danger: Slush," *Flight*, October 16, 1959) it is interesting to read that B.E.A.'s advice to pilots is that they should never attempt to take off if there is more than *two inches* of slush, loose snow or water on the runway. The danger signals, says the pamphlet, are (1) difficulty in getting the nosewheel off the ground and (2) pitching motion which is difficult to control.

Other points of winter warning are that during pre-flight inspection pilots should ensure that every part of the aircraft is free from ice and snow: "You are responsible for seeing that this is done—never take it for granted that the other chap is right on the ball"—and that the engine intakes, props, wings and control surfaces merit special attention to "prevent that sinking feeling."

DC-7F FOR FREIGHT

DELIVERED to American Airlines last month, the first of ten DC-7Fs was to go into service on the New York-Chicago - Los Angeles transcontinental route on October 25. The new fleet, which is being converted for American by Douglas at a cost of about £173,000 ($485,950) per aircraft supplements another ten DC-6As which the airline use entirely for freight. In its DC-7Fs, DC-6As and the cargo holds of passenger aircraft, American this year hopes to carry 100m ton-miles of freight. The conversion work, which takes about five months, involves replacing the floor with a cargo floor stressed to 200 lb/sq ft (84 lb per running inch) very similar to that of the DC-6A, but 40in longer. DC-6A cargo doors are also used and, with the increased size of aperture, pressurization is limited to 4.16 lb/sq in. But unlike the DC-6A, the DC-7F can carry its full payload (33,500 lb) over transcontinental stage-lengths. Other airlines planning on DC-7Fs are PanAm, who are receiving the first of ten in December, and United, who have ordered six conversions from Douglas.

This month, ten months after its first flight, the Convair 880 begins its F.A.A. full-certification tests. Here is the first of the Convair 880s for T.W.A., which will be delivered for training this month and go into all first class service next spring

COMET 4Cs FOR MEXICANA

THE Comet 4 order book rose last week to 39 when Mexicana (Compañia Mexicana de Aviaçion) contracted to purchase three Comet 4Cs. The first two will be delivered next month, the third in mid-1960. Value of the contract, including spares and ground equipment, is $14m (£5m). A statement issued on October 30 by Mexicana included the following passages, here slightly abridged:—

"The Comet 4C has a take-off capability and rate of climb enabling it to comply easily with stringent anti-noise regulations. It is particularly well suited because of its performance into and out of Mexico City. The combination of 7,350ft altitude, temperature and runway length in the Mexican capital places certain restrictions on jet operation. Tests of the Comet 4C . . . showed it was best qualified from Mexicana's standpoint. In one of these tests, a Comet 4 fully loaded for a flight of 2,680 statute miles to Lima easily operated from the 8,200ft runway then in use [longest runway is 9,840ft] in hot weather and zero wind.

"After exhaustive surveys of all types of jet and propeller aircraft Mexicana selected the Comet. Adaptability of the airliner to Mexicana's volume of traffic was a factor in its selection. The Comets will carry 22 first-class and 64 tourist-class passengers, a configuration which will allow greater flight frequency than with larger aircraft. Surveys have indicated that with Mexicana's traffic-potential an 86-seater would ensure a more profitable operation than would a larger jet."

Mexicana is a Pan American affiliate, 42 per cent of the stock being owned by the American airline. It operates domestic services to 26 cities in Mexico and international flights to Los Angeles, Chicago and Havana. The Comets will presumably replace C.M.A.'s four DC-7Cs on the international flights.

A de Havilland statement last week said that negotiations for further Comet sales were "at an advanced stage." The French independent U.A.T. (a Comet 1A operator in 1953-54) is known to be studying the Comet 4C, and M. Roger Loubry, a director of U.A.T., told *Flight* last week that the 4C appeared to meet their requirements for a jet that would operate from African airports that the big jets could not use. No decision had, however, been made.

Comet sales and orders to date are as follows:—

Royal Air Force Transport Command, ten Comet 2 (in service since June 1956); **Royal Canadian Air Force Transport Command,** two Comet 1A (in service since summer, 1957); **B.O.A.C.,** 19 Comet 4 (in service since October 4, 1958—16 delivered to date); **Aerolineas Argentinas,** six Comet 4 (in service since April 16, 1959—three delivered, one subsequently written off); **British European Airways,** seven Comet 4B (deliveries due to start tomorrow, November 7—see pages 489 and 490); **E.A.A.C.,** two Comet 4 (1960 delivery); **Olympic Airways,** two Comet 4B (spring 1960 delivery); **Mexicana,** three Comet 4C.

RENFREW OR ABBOTSINCH?

UNDER consideration in Scotland is a plan to develop Abbotsinch instead of Renfrew as Glasgow's municipal airport. Doubts have recently been growing about Renfrew's capacity for extension; though in abeyance for some time, a proposal by the Clyde Trust to extend the nearby George V dock still represents a major threat to Scotland's oldest operational airport.

It seems unlikely that any objections about a change of site would come from the airlines; thoughts have already been voiced that Renfrew (the main runway is 5,789ft long) might be a bit of a squeeze for B.E.A.'s Vanguards in bad weather, and although the 6,000ft main runway at Abbotsinch is only a little longer, it would not be difficult to extend and the approaches are good. When the Navy laid runways there during the war, thousands of tons of rubble from blitzed sites in Glasgow had to be poured in to prevent them sinking, but recent borings to determine load-bearing are said to have proved surprisingly satisfactory.

If the Navy relinquishes Abbotsinch—as has been forecast—the work of developing a new civil airport would take more than two years and would cost over £1m. A proportion of this sum might be defrayed by the sale of Renfrew, where an imposing new terminal was built five years ago. Last year 443,000 passengers used Renfrew on scheduled services, making it the third busiest airport in the United Kingdom (after Manchester and London).

WHAT IS A SCHEDULED SERVICE?

THE protest by B.O.A.C. to the Ministry of Aviation about a recent Eagle DC-6C service to London from Hong Kong raises, not for the first time, the question posed above.

The controversial flight was primarily a ship's crew charter: 59 seamen were booked, and to fill up the aircraft Eagle advertised in the Hong Kong newspapers that 20 seats were available to London at £136—the "V.L.F." fare which Eagle have sought (but not yet been granted) permission to offer regularly. They sold tickets to 13 passengers, not a bad response considering the shortness of the notice (two weeks).

Obviously, this flight could not be described as a scheduled service, and B.O.A.C. protested "because we felt our silence would imply approval." Mr. Harold Bamberg of Eagle said: "I knew I was within the law. I am quite entitled to make special flights at these fares provided I do not operate a regular schedule. I am not trying to prove anything. I am in business. I had an empty airliner coming through Hong Kong and I saw a chance to do business with it."

Off from a misty Hatfield for the first time on October 31 was the first of the three long fuselage, large wing Comet 4Cs for Mexicana. It was flown by Pat Fillingham and was airborne for over 4½ hr

Will Eagle continue to advertise V.L.F. seats to the public in this way? They can do so provided such flights do not, within the legal definition of the term, become scheduled services. Everything turns upon this definition, which is as follows (Air Corporations Act):—

"[A scheduled service is] one of a series of journeys which are undertaken between the same two places and which together amount to a systematic service operated in such a manner that the benefits thereof are available to members of the public from time to time seeking to take advantage of it."

As Eagle have reminded people, the loopholes in this law are wide enough to fly a V.L.F. DC-6C through. Provided Eagle's offers to the public do not become "systematic," the company is within the law. Historic forces are seen in action: it has always been the "irregular" carriers who have exerted low-fare pressures on the regulars.

F.A.A.'s PROJECT FRIENDSHIP

UNDER the project title of "Friendship," the F.A.A. are now putting into action their plan for the unification of U.S. civil and military air traffic control. It involves taking over 2,095 military facilities, to man which the Agency will have to recruit another 9,000 traffic controllers and 6,000 maintenance technicians.

The F.A.A. were charged with the task by the Federal Aviation Act of 1958, passed by Congress 14 months ago; indeed, the Agency was established to support the common needs of military and civil aviation in the United States, and to develop a unified air navigation and traffic control system.

At the moment the military traffic control facilities that the F.A.A. are to take over have a total staff of about 20,000. The Agency reckons that the job can be done by a staff of 13,300—3,500 of whom will serve overseas—but to get the training programme completed in time two new buildings are to be erected at the Aeronautical Centre at Oklahoma City.

Summing up the F.A.A.'s big scheme, the administrator, Mr. E. R. Quesada, said that "Project Friendship makes military aviation a special partner in a common venture for the better use . . . of the nation's airspace. In this respect, it represents the most progressive step taken to date to attain an A.T.C. service that this country needs and deserves."

Footnote: In a message to the Directors-General of Civil Aviation meeting in Brussels last week to discuss Euro-control (see "New Techniques in Air Transport," page 477 of last week's issue) Mr. Duncan Sandys, Minister of Aviation, said: "The rapid growth of jet services . . . makes it urgently necessary to establish an integrated system of traffic control in the upper airspace. The British Government is therefore very pleased to join with the governments of its European neighbours . . . with a view to setting up an effective common organization for the whole region."

SHIPPING SINKING

SEA traffic statistics recently compiled by the Board of Trade have a sad tale to tell North Atlantic shipowners. While the volume of air traffic, first-class and economy, has been booming the total sea traffic in each direction fell by 11 per cent.

Last year's fall in sea traffic was explained by shipping spokesmen as an exceptional consequence of the unusually high level attained in 1957, when half of Europe was apparently trying to emigrate to North America. If westbound figures were excluded as being affected by emigrant traffic, then the remaining eastbound shipping total was seen to have increased slowly.

But figures for the first half of 1959 show that eastbound traffic to Britain fell by 11 per cent from 72,000 to 64,000 passengers, while westbound movement from Britain to the U.S. and Canada fell by a similar percentage from 63,000 to 56,000 passengers. Compared with the record of total North America/U.K. traffic of 160,000 passengers in the first half of 1957, this year's shipping amounted to only 119,000—a decline of 25 per cent.

Canadian Pacific's new European passenger manager is Mr. T. G. Hughes (right). His assistant is Mr. R. J. Horden and he is supported by Messrs. J. F. G. Swan and J. A. M. Watson, respectively regional sales and traffic managers (air)

AIR COMMERCE...

AIR UNION PROGRESS

NO one ever imagined that the bringing together of the European partners in Air Union could be an easy process. But the work has gone on and through a series of conferences and committees active progress is being made. Sabena proposals relating to the inclusion in Air Union of traffic on the Belgian Congo route and of international traffic originating in the Congo and Ruanda-Urundi area have now been fully accepted. This traffic is additional to the original agreed 10 per cent contribution of Sabena to the total international traffic of Air Union.

One of the most difficult tasks facing the four airlines is to decide upon methods of reimbursement for services and means of sharing revenue. Decisions on these matters have yet to be taken, but they may be forthcoming before the next meeting of the executive committee.

Another idea under consideration by Air Union is the inclusion of Sabena's helicopter operations. This is regarded favourably, and a working party, under Mr. Naômé of Sabena, has been formed to study the pattern of the helicopter network within the general Air Union route system.

As the Union develops more is becoming clear about the way in which it is to be organized. A programme bureau with a permanent staff will be directed by M. Rettier, formerly head of the Air France programme committee, and general advisers to other committees have been selected. Their tasks will be shared as follows:

Air France: commercial committee; *Alitalia:* ground operations, international relations and personnel duties; *Lufthansa:* administration and finance, legal and air operations committees; *Sabena:* equipment committee. The legal committee is separate from the legal committee originally in charge of the constitution and foundation of Air Union.

A.A. REPORTS ON THE 707

AS well as making modifications to the JT3s of its 707-120 fleet to increase power from 13,000 lb to 13,500 lb thrust (*Flight*, October 23), American Airlines are also planning modifications to the wings. A leading edge "glove" will be fitted to improve high-speed capabilities, and additional leading edge flaps will be installed to improve low-speed characteristics and presumably to ameliorate the runway length and climb out limitations imposed by the S.R.422A amendment to the F.A.A. airworthiness requirements. The wing modifications are long-term, due to begin in a year's time, whereas the engine modifications were due to begin last Sunday, November 1.

Reporting on the first year of 707 operations, the airline's director of equipment research, Mr. F. W. Kolk, says that mechanical reliability has proved "somewhat better" for the 707 than for the airline's Electras, whose propeller control system has been involved in a fairly high proportion of in-flight turboprop shut-downs. On the other hand, the turboprops appear to have a higher rate of overhaul life-increase than the turbojets.

As regards transcontinental New York - Los Angeles regularity, Mr. Kolk reports "a slight degree of over-optimism" in early planning. Assuming average conditions the flight can be made with a fair amount of margin. "If, however, we assume a full load of passengers, not quite the worst wind on record, optimum altitude blocked off by other traffic and the kind of fuel reserve we must carry when it is raining in Los Angeles, the sum of the parts becomes somewhat greater than the whole and passenger load tends to dwindle to insignificance."

BREVITIES

The Tu-114 is to go into service before the end of the year between Moscow and Khabarovsk, and Moscow and Peking.

C.S.A. is to operate a fleet of Il-18s on international services next year. Super-Aeros will be exported to the U.S.S.R. in part payment.

Qantas' first round-the-world Boeing 707 service was inaugurated on October 27, the aircraft leaving Sydney with 60 passengers. The service is scheduled to take 56 hours' flying time.

Eleven of T.A.A.'s DC-3s are being offered for sale by W. S. Shackleton Ltd., of 175 Piccadilly, London, W.1. They range in price from £8,000 to £15,000.

Avianca and L.A.V. are holding discussions about a pooling agreement to meet jet competition in South America. There is also a possibility that Panama and Ecuador may be invited to join.

Because the runways at Eastleigh are unsuitable for year-round operation, as from November 18 Silver City is to transfer to Hurn its air ferry services to Cherbourg and Jersey.

Coolidge Airport, Antigua—which is administered by the Director of Civil Aviation for the Leeward and Windward Islands—is to be equipped with G.E.C. airfield lighting. The contract is worth about £6,000.

Wellington's new international airport at Rongotai was officially opened by Viscount Cobham on October 24, but bad weather forced the postponement of an air pageant.

On October 11 Varig achieved a 203-mile glide with a Caravelle, starting at 40,000ft over Passo Funde in the Province of Rio Grande do Sul with both engines fully throttled back. The aircraft remained in the glide for 40 min.

An exhibition of aeronautical drawings that have appeared in *Punch* over the past 118 years is being held in the exhibition hall in Queen's Building at London Airport. It was opened by Russell Brockbank on October 26 and will last for at least four weeks.

The Chrysler Corporation of Michigan is to design, construct and test the prototype mobile lounge for Dulles International Airport at Washington, DC. The contract is for $750,000 and the prototype should be completed by the end of April 1960. Service tests at a major airport will start on August 1 of the same year, and a lounge is expected to be in operation at Dulles in early 1961.

The Douglas Aircraft Company say that, as a result of continued "heavy development costs and inventory write downs," they have lost more than £8,390,000 during the first nine months of the current financial year. Development costs for the DC-8 this year have been £9,640,000 compared with £13,206,000 in the first nine months of last year. At the end of the third quarter sales were £235,000,000 compared with £317,000,000 for the same period in 1958.

Philippine Air Lines have ordered one Viscount 745 from Vickers' stock, bringing Viscount sales to 408.

Letters posted in Pakistan are now being sent by air whenever services are available. Introduction of the scheme will cost Rs.1,000,000 a year.

It is reported from Beirut that planning for the pan-Arab aviation company, Air Arab, provides for £17m capital and an initial fleet of three long-range and three medium-range jets.

During the past 12 months Overseas Aviation has carried over 150,000 passengers and flown more than 78,000,000 passenger miles. The fleet consists of five Argonauts with 65 seats and three 36-seat Vikings.

An Olympic Airways DC-3 on a flight from Athens to Thessaloniki crashed on October 29 near Tanagra, north of Athens. All 15 passengers and crew of three were killed.

New B.O.A.C. Comet services to Sydney and Britannia services to Tel Aviv started last Sunday. The fastest London - Sydney time will be 33 hr 15 min; there will be five services per week on this route and two to Israel.

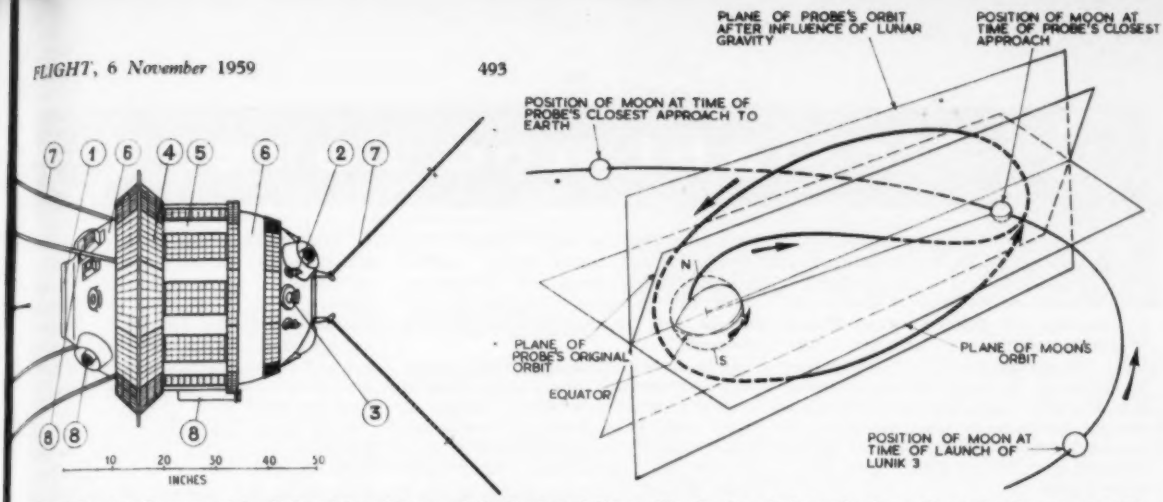
Riddle has now cancelled its provisional order for four AW.650 Argosies. The airline is financially hard pressed and is trying to reduce operating losses by $100,000 a month (on $400,000 gross monthly revenue) to break even.

Lufthansa is asking the West German Federal Transport Ministry to curb foreign airliners' Fifth Freedom rights in West Germany. The airline claim that their big deficit in 1958 was partly caused by low load-factors on domestic services.

An order for DC-8s, powered by Rolls-Royce Conway RCo.15s, has been placed by C.P.A.L. They are to buy four for delivery in 1961 at a price of £8.6m, and have placed an option on a further five. A spokesman for the airline has said that "it would be quite wrong to assume that the airline is not going to look at Comets again."

From December 1 the F.A.A. are to operate—regardless of weather conditions—daily helicopter flights from Philadelphia to New York and from Bridgeport, Conn, to the F.A.A. National Aviation Facilities Experimental Center at Atlantic City. The experiment is designed to test air traffic control for rotary-wing aircraft in I.M.C. and to co-ordinate their flight with fixed-wing traffic.

Five major airports in Ethiopia are to be constructed or extensively improved to the designs of a firm of U.S. consulting engineers. Locations will be Addis Ababa, Asmara, Dire Dawa, Jimma and Bahar Dar. The improvements will be financed out of the $24m credit granted by the Ex-Im Bank, some of which has already been used for the purchase of three new DC-6Bs. The airport programme should be completed by 1963.


PLANE OF PROBE'S ORBIT AFTER INFLUENCE OF LUNAR GRAVITY
POSITION OF MOON AT TIME OF PROBE'S CLOSEST APPROACH
POSITION OF MOON AT TIME OF PROBE'S CLOSEST APPROACH TO EARTH
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INCHES

Official Russian diagrams of Lunik 3 and its orbit around the Earth and Moon. The drawing of the probe shows (1) window for cameras, (2) orientation system motor, (3) solar monitor, (4) solar battery section, (5) shutters of heat regulating system, (6) thermo-screens, (7) aerials and (8) measuring devices, and the arrow on the left is pointing towards the Moon

Missiles and Spaceflight

PHOTOGRAPHING THE MOON

The first photographs of the far side of the Moon taken by the Soviet "automatic interplanetary station" Lunik 3 were published on October 27. Earlier, further details had been given of the probe and its flight (see diagrams above), and of the techniques used in taking, processing and transmitting the photographs.

"For photographing the Moon," the news agency Tass stated, "the automatic interplanetary station was supplied with a system of orientation and photo-television apparatus with special equipment for automatically processing the film." Photographs (on 35 mm film, using lenses of 200 and 500 mm focal length) were taken during a 40-minute period on October 7 when the probe was 37,000-43,000 miles from the surface of the Moon, and these pictures were transmitted to Earth from distances up to about 300,000 miles. It was estimated that the probe would make 11 or 12 orbits around the Earth, taking about six months, and would then re-enter the Earth's atmosphere and burn up.

"At the beginning of the (orientation) operation," an article in *Pravda* reported, "the orientation system, which includes optical and gyroscopic transducers, logical electronic computers and controlling motors, first of all stopped the free rotation of the automatic interplanetary station around its centre of gravity, which began at the moment of separation from the last stage of the carrier rocket. . . . The trajectory was selected in such a way that at the moment of taking the photographs the station should lie approximately on a straight line connecting the Sun and the Moon. . . . The station's lower end was first of all directed towards the Sun with the help of the solar transducers; thereby the optical axes of the cameras were aimed in the opposite direction—towards the Moon. A special optical device then switched off the orientation to the Sun and carried out a precise orientation towards the Moon. . . . After all the pictures were exposed, the orientation system was switched off. At the moment of the system's switching off, it imparted to the automatic interplanetary station a settled rate of rotation at a certain angular velocity selected in such a way as to improve the temperature regime while at the same time excluding the rotation's influencing the functioning of the scientific instruments. . . .

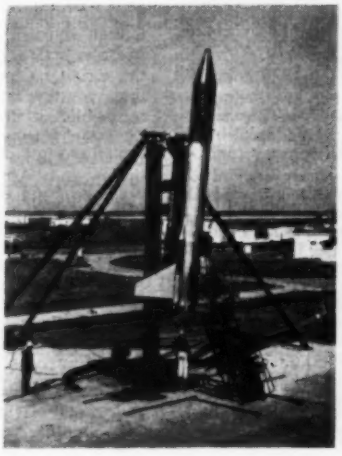
"After the photographs were taken the film passed into a small automatic processing device where it was developed and fixed. . . . To transform the images on the negative into electric signals a small pick-up electronic ray tube capable of a high resolution power, and a highly stable photo-electronic multiplier, were used. . . . The images of the Moon were transmitted on the radio channel which at the same time served to measure the parameters of the movement of the station itself, namely the distance, velocity and angular co-ordinates, as well as for the transmission of the results of scientific experiments with the help of telemetric instruments."

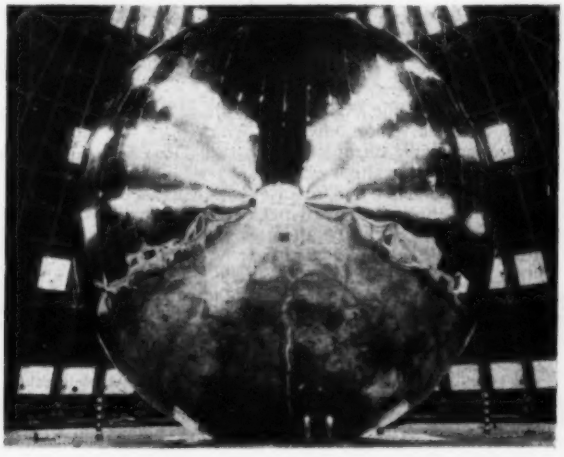
It was announced on October 14 by the U.S. Army that the first successful firing of a Nike Zeus test vehicle took place on that date at White Sands. The first broke up in the air last August.

The Ministry of Aviation stated on October 30 that the fifth Black Knight research vehicle (RAE/Saunders-Roe/Bristol Siddeley) achieved a record height in excess of 500 miles during its very successful flight from Woomera.

More than one-eighth by weight of the propellant used in the Polaris fleet ballistic missile is said to be powdered aluminium. Moreover, the charges are cast into an aluminium cylinder which is consumed during combustion (pressure is taken by the main stainless-steel missile body).

Received too late for inclusion later in this issue, comes the news that the Sergeant ballistic missile of the U.S. Army is provided with controllable air brakes to modify the trajectory during the terminal phase of its flight.





On October 28 a two-stage rocket was launched from Wallops Island, Virginia, releasing at an altitude of 250 miles a 100ft diameter, aluminium-coated Mylar inflatable balloon. The rocket (right) comprised a Sergeant plus two Recruits as first stage, and a second-stage X-248. The payload was contained in a 26½in sphere in the nosecone, and the balloon is seen (far right) during a preliminary inflation test at Langley Field. The test concerned the development of inflatable satellites for communications

Straight and Level

ONCE upon a time a respected and air-minded Royal Prince made a useful effort to help light aviation in this country. Not by words but by example—by going down to White Waltham and flying a Turbulent ultra-light. From the grin on his face when he taxied in he had obviously enjoyed it immensely, and from the stories and pictures in the newspapers the next day one would have thought that the light-aviation enthusiasts would have been quite happy too.

But no. "Everyone was fed up," complained one enthusiast. "We were furious," cried another enthusiast. "We feel very strongly about this," muttered a third enthusiast. The enthusiasts explained that they had not been allowed to fly for 2½ hours because their base was very near White Waltham and official regulations said everybody, including enthusiasts, must keep clear when Royal Princes were airborne.

"If the Prince wants to fly in small aircraft, why shouldn't he take the same chances that the rest of us have to take?" asked a prominent White Waltham enthusiast. But the answer to this was obvious, even to his fellow-enthusiasts.

When the Prince heard about all this fuss he was very upset, because he had not wanted to stop anyone flying at all—least of all the enthusiasts. So one of the Prince's equerries wrote to the enthusiasts, saying that if they thought *they* had difficulties getting into the air they should try being a Prince sometime because he had a lot more difficulties than they did—and not just for 2½ hours on a Saturday morning, either.

The moral of the story seems to be that you just can't win—not if you're a Prince. But if you're an enthusiast, you can have everything both ways.

● The special Straight and Level committee which has been studying the vexed question of a British supersonic airliner issued its report and recommendations last week. Chairman of the committee, Dr. J. Nit, said at a news conference:

"We are convinced that such an airliner should be a co-operative effort with the Europeans, with the Commonwealth, with the Americans, with Europe and the Commonwealth, with the Americans and Europe, or with the Commonwealth and the Americans."

Dr. Nit added: "The precise consortium, like the question of speed and timing, must, of course, be a matter for the experts to decide."

Straight and Level's special committee investigating the future of British space research is expected to issue its report shortly.

● "In the study of aircraft accident causes it has become important to discover all the contributory factors which seem to make human errors inevitable. Unfortunately the word 'error' itself carries an emotional charge which implies condemnation and this lack of objectivity hampers investigation, research, and ultimately, training programmes.

"The only terminology which could be free from this disadvantage would involve entirely new words. Some of your readers might have invaluable ideas, which could be presented at a forthcoming conference. The new word should have the meaning of 'a variation from optimum (or ideal) conduct' and should be concise, with some vivid appeal on both sides of the Atlantic.

"My own notions have not got further than the miserable neologism 'variact.' I must rely on your readers to do better."
—A letter in *The Sunday Times*, from H. Caplan. I think it deserves the widest attention, so I have reproduced it in full. Please forward suggestions to the newspaper.

Haut-Mode Couture,
London, W.1

Dear Susan and Elizabeth

Although I have previously seen you both on B.E.A. services, I was simply shattered when I saw you in this photograph, sent to me by your publicity department. I scarcely recognised you. Of course I must say that you would both look marvellous in anything. But even you do nothing for your airline's proposed new stewardess's uniform. Those TERRIBLE hats! Does Lady Douglas really approve? Surely not.

Meanwhile, I do hope I shall know you when we meet again.

Yours ever,
Hamish Haut-Mode
Chief Fashion Adviser, Straight and Level

● Did you know that there is an airline which has had 100 per cent regularity on its scheduled services for the past ten years? Well, there is. The French Aeropostale service, run by Air France, has operated 13 DC-3s on a night mail network to French provincial towns exactly on schedule every night between 11 p.m. and 3 a.m.

Each DC-3 takes off with sufficient fuel to fly from Paris to Marseilles and back non-stop with a three-tonne payload—with no special blind-landing equipment beyond a radio altimeter. At some airfields they can use only a radio compass and radio altimeter, but they land in any weather. Sometimes they have only 150yd to spare beyond the landing run. Often they stop only one engine while unloading.

The crews are naturally some of the most highly trained instrument-flying pilots there are. They have developed their own special instrument panel, using standard instruments carefully arranged, together with a special stop-watch correctly positioned. They have special maintenance support to ensure 100 per cent serviceability. And, as I say, they have achieved 100 per cent regularity for ten years.

● A friend of mine was recently looking over a resonance chamber for acoustical experiments. In it sound-reflecting panels had been suspended from the ceiling in a "random pattern."

Wondering how a workman, given assorted panels and a regular pattern in the ceiling, could in fact have achieved "randomicity" (the man said the pattern was "randomized"), my friend asked whether the arrangement was in fact random. Surely *some* sort of pattern must have resulted? The answer was that the arrangement was to be *calibrated* to make sure that it was random.

Have we now an exact science of inexactitude?

● Not quite full marks to official British efforts to foster exports to Mexico. The organization concerned, the British Chamber of Commerce in that country, has published a pamphlet to publicize its excellent brainchild—the permanent British exhibition in Mexico City. Among the pamphlet's illustrations of British products is the Caravelle, the pride of France.

Never mind, despite this *faux pas*, the Mexicans have bought Comets (see page 491).

● "The whole [aircraft] industry is in a state which can only be described as one of disturbing disarray"—Mr. John Rankin (Glasgow, Govan) in the House of Commons last week.

More shotgun weddings?

ROGER BACON

Correspondence

The Editor of "Flight" is not necessarily in agreement with the views expressed by correspondents in these columns. Names and addresses of writers, not for publication in detail, must in all cases accompany letters.

Viscount Utilization

IN a recent issue of your journal I read an article commending B.E.A. on achieving an annual utilization rate for 1958-59 of 2,468 hours with their Viscount 701s.

Without wishing in any way to detract from this performance I feel it is worth recording that Middle East Airlines, an airline much in the news these days, had an average utilization of 2,742 hours over a similar period. M.E.A.'s routes are of much the same pattern as B.E.A.'s and their fleet consists of only seven Viscounts. They have planned for a utilization of over 3,400 hours per aircraft for 1960.

My company claims some of the credit, as all maintenance engineering is contracted to us.

R. S. COLVIN,
Chief Executive,
Beirut, Lebanon. Mideast Aircraft Service Co. S.A.

Bouquet . . .

FROM time to time the Press reminds us of the fabulous prices extracted for oil paintings by the great masters, but studying the drawings of the Hovercraft which appeared in your September 11 issue, and others like it which have appeared in your fine journal, I wonder if our sense of values is not terribly distorted.

Incidentally, I have been a reader for the past 49 years and now wish to express my indebtedness to *Flight* for a life of great interest. I remember when waiting for the next issue became intolerable.

Winnipeg, Canada. ROBERT M. STEPHENS.

. . . and Brickbat

IN his review of *The Seven Skies* ("Aeronautical Bookshelf," October 23) J. C. S. writes of "those unfamiliar with such names as Holt-Thomas or Woods Humphrey." Can it be that J. C. S. is not sufficiently familiar with George Woods-Humph*e*ry's name to know how to spell it?

London, S.W.5. GEOFFREY DORMAN.

Fares and Revenue

PEOPLE in the British aircraft industry would like to see low airline fares introduced for at least two good reasons: (a) The traffic would undoubtedly increase, and with it the orders for more aeroplanes; and (b) they would be able to fly farther, or more often, themselves, e.g., on holidays.

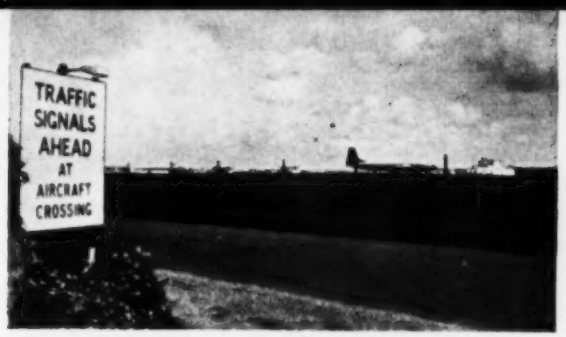
But we have to bear in mind that the commercial success or otherwise of air transport is dependent upon the difference between two enormous quantities: 1 per cent of the I.A.T.A. traffic revenue represents about £15 million, so it makes a world of difference whether the 1 per cent is a profit or a loss.

Your contributor J. M. R. ("Down Fares, Up Revenues," page 412, October 16) reaches the conclusion, from reading the I.A.T.A. Traffic Statistics No. 3 (July 1959), that it is "obvious" that increased traffic in the second half of 1958 must have meant increased profits. Is it so obvious?

The figures certainly show that the gross revenue was up by 19.5 per cent but the 8½ per cent fare increase over 1957 was authorized because expenses were up at least correspondingly—so one must regard the 19½ per cent increase as worth only about 10 per cent more in revenue relative to costs of the traffic on the 1957 scale. The traffic increased 31 per cent so the airlines had to handle 31 per cent more traffic for effectively 10 per cent more money: put in these terms, extra profits are not quite so "obvious."

Unless their aircraft were previously not being utilized to their full ton-miles capability, the high-density seats could be filled only at the expense of cutting range, thus resulting in more passengers, fewer miles and the same number of passenger miles for less revenue.

However, I agree with J. M. R. in one respect: the average load-factors achieved must seem, to those of your readers concerned with the construction rather than with the operation of aircraft, disappointingly low. Presumably the airlines know their business well enough to judge when cutting schedules for the purpose of increasing load-factors is likely to lose them *money*—and that is presumably well beyond the point when they start to lose passengers (e.g., if they carried 20 per cent fewer passengers but were able to raise their average load factors by 5 per cent, I think they would be better off financially). But one way to make up the load when the passenger load-factor is low is by freight; this was well understood by an Australian operator who once said to the writer, "If an aeroplane is about to take off at 10 lb under the maximum authorized take-off weight, we look round for another parcel."



Beware of take-offs (see letter from R. G. Avent)

Obviously the indirect costs of handling freight are likely to be higher per unit of weight for parcels carried in passenger aeroplanes than in "all-freight" aircraft, but over long ranges the direct cost must be a fairly high percentage of the total; therefore reducing the direct cost by carrying the freight almost for nothing in passenger aircraft should be quite profitable. The unused chairs can be a problem, but there are various ways of overcoming this.

Lytham St. Annes, Lancs. J. F. FOSS.

Priority Traffic

MANY of your older readers will, no doubt, remember the level-crossing across the road in the early days of Croydon Airport. I was recently interested to see its modern counterpart at Hurn [photograph above—Ed.]. The runway at this point stops just short of the road, and on the five-barred gate in the hedge some wag had chalked "Emergency Exit."

Southampton, Hants. R. G. AVENT.

North Atlantic Springboards

WITH reference to the paragraph under the above heading (p. 354, October 9), while agreeing that the development of Prestwick is primarily in Scotland's interest, may I point out that Prestwick is officially designated the No. 2 U.K. airport? Given feeder services, such development could now, more than ever before, benefit much of the country and in particular Northern Ireland, Northern England and parts of the Midlands.

It is becoming increasingly clear that in a country as small as the U.K. the new jet transports, because of exacting operational requirements (chiefly runway length and extension costs of airports, economical stage-lengths and other factors) will operate into fewer airports than their piston-engined counterparts. Prestwick, apart from its well-known freedom from fog, is especially suitable for transatlantic jet operations for two reasons: it is situated in a less congested traffic-control zone and with low frequency of aircraft movements can rapidly accept and despatch jets; and there is an almost complete absence of habitation on the line of approach and climb-out which jets would take.

If the benefits of considerably faster transatlantic crossing by jet transports are to be passed on to the rest of the country then greater use will have to be made of feeder services to and from jet centres. What is not perhaps generally realized is that if some of these services operated via Prestwick instead of London passengers would, because of the former's geographical position in conjunction with its placing on the transatlantic fare structure, enjoy an overall saving of one to two hours on total journey time and some £6-£12 on air fare, depending how far north of London their destination lay. Such services would also help ease the strain on the London Control Zone.

Unless B.E.A. are prepared to depart from their policy of centralizing internal services at Glasgow (Renfrew), some 27 miles from Prestwick, there would appear to be prospects in this field for the independents.

Ayr. DAVID REID.

FORTHCOMING EVENTS

Nov. 3-6. Institute of Welding: Autumn Meeting.
Nov. 6. Helicopter Association: "Application of the Jet Flap to Rotor Control," by R. Dorand.
Nov. 9. Institute of Transport: Lectures, including "Air Forestructures," by J. L. Grumbridge.
Nov. 10. Photogrammetric Society: Brains Trust.
Nov. 11. R.Ae.S. Graduates' and Students' Section: "Flight Testing of Rotorcraft," by S/L. W. R. Gellatly.
Nov. 13. R.Ae.S. Agricultural Aviation Group: Discussion on the Cranfield Conference.
Nov. 17. R.Ae.S.: "Magnetogasdynamics," by J. A. Shercliff.
Nov. 17-18. Institute of Aeronautical Sciences: National Turbine Powered Air Transportation Meeting, San Francisco.
Nov. 19. R.Ae.S.: Fifteenth British Commonwealth Lecture, "Air Survey and Newly Developed Territories," by W. P. Smith.
Nov. 20. R.Ae.S. Graduates' and Students' Section: Winter Dance.
Nov. 20. Institute of Navigation: "Radiometry, Radio-Astronomy and Infra-red Techniques," by C. M. Cade.

R.Ae.S. Branch Fixtures (to Nov. 13): Nov. 11, *Bristol*, film show; *Brough*, Sixth Cayley Memorial Lecture, "The Royal Aircraft Factory," by Sir George Gardner; *Chester*, "Automobile Aerodynamics," by F. A. Costin. Nov. 12, *Isle of Wight*, annual dinner.

The Royal Whirlwinds

HELICOPTERS FOR THE QUEEN'S FLIGHT: WESTLAND BUILD TWO HCC Mk 8s

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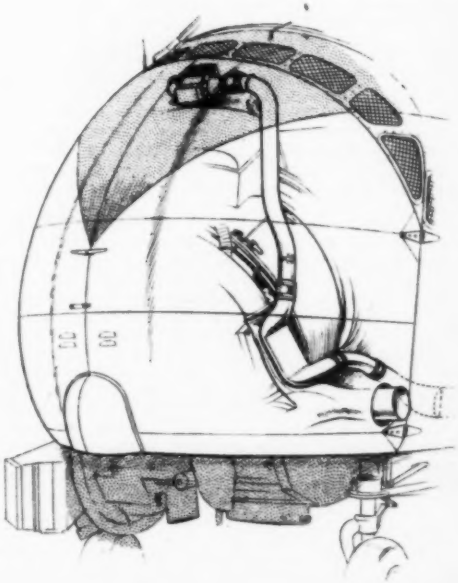
Westland are fitting the 400 lb winch driven by an Integral hydraulic motor and weighing between 60 and 70 lb. The unit can be rapidly attached to the fuselage above the main door by four bolts and three pipe connections. The winch can be controlled either from a switch on top of the control column or from another switch on a flexible lead inside the cabin. Among several small special modifications are locking fuel-tank filler caps and chromium-plated baseplates for the static vents. Flashing beacons are fitted above and below the fuselage and an electric discharger for two Schermuly landing flares is mounted to starboard below the equipment bay aft of the cabin.

"Flight" drawings

Left, two pairs of facing V.I.P. seats, by Rumbold. Note the two entry steps, hand rail, winch and fresh-air scoops

Below, the cabin-air blower (top) and duct welded over spacer bars to the exhaust manifold for heat-exchange. The installation of the Alvis Leonides Major is otherwise virtually standard



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No alterations have been made to the engine installation. As usual, the bearer beams are shielded by stainless steel, but the individual fire-detectors have been replaced by Graviner Firewire continuous detectors. A single bottle discharges extinguishing fluid through spray rings around the engine.

All military fittings have, of course, been removed from the cabin, and extensive soundproofing, air-conditioning and seating arrangements provided. For heating, a Plannair blower draws air from the cooling intake grille ahead of the windscreen and delivers it through a heat exchanger in which the exhaust pipe and the heating duct are welded to a row of spacer bars (the latter ensure that no contamination of the cabin can occur unless both pipe and duct happen to be fractured next to each other). Heating air then passes through a spill valve controlled from the cockpit and into the main cabin through floor-level louvres. The pilot will control the cabin temperature with the spill valve by reference to a temperature indicator. Two ram-air intakes set high up in the starboard wall of the cabin admit fresh air through adjustable nozzles. Main access to the cabin is by the standard sliding door, but two broad footsteps replace the simpler step of standard machines.

The larger number of windows of the civil version is retained, one of them, aft of the port side, being an escape hatch. Additionally, the main door is jettisonable and all windows can be pushed out after rip strips in the rubber mountings have been torn away. The windows can be covered by roller blinds.

The cabin colour scheme is pale grey with dark green seats. Two 0.5in-thick mats of Fibreglass with an air space between them form the principal soundproofing element between the external skin and interior trim; the latter has in itself a soundproofing function, as it consists either of perforated Vynide sheet or metal intended to damp noise inside the cabin. With such protection, the noise level inside the HCC Mk 8 should be exceptionally low.

Other special facilities include individual reading lights for the two seats in the back of the cabin, a telephone (for communication between cabin and flight deck) which can be stowed at two points in the cabin, and a trap-door for passing messages from the cabin to the flight deck. A main light is mounted in the cabin ceiling, and a further strong light above the main door. Close to this, too, is the "fasten seat-belts" sign.

There are three main categories of seat, and corresponding seating layouts. It is envisaged that members of the Royal Family would sit in two low-backed adjustable chairs facing forwards in the rear of the cabin, with a wooden chair-side cabinet between them. A tall mirror is mounted on the rear wall above this cabinet. Immediately forward of these would be a pair of rather higher-backed chairs for equerries, also facing forwards, and two or three rather plainer seats at the front of the cabin for additional personnel. With these three basic types of seat, it is possible to arrange the cabin either to carry eight people in lightweight, tourist-type seats in a three, two, three layout, or to place two pairs of V.I.P. seats facing each other. The direction in which these seats face is dictated by considerations of leg-room and privacy; in a helicopter there is probably no particular safety-advantage in rearward-facing seating. Siebe Gorman are responsible for the lap straps, Frankenstein for the lifebelts, and Rumbold for the seats themselves.

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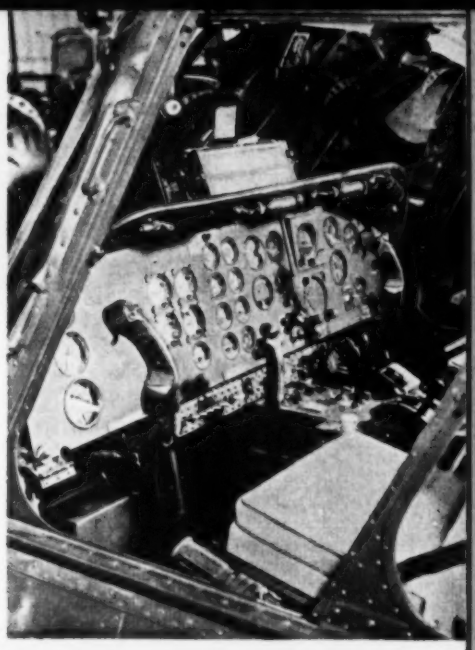

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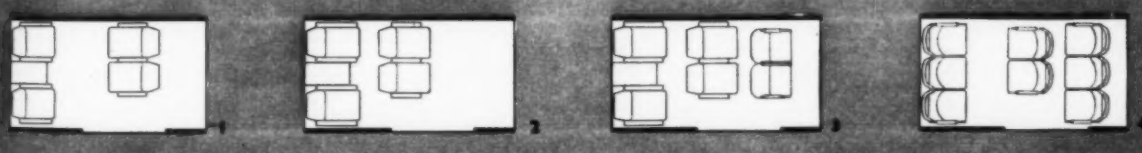

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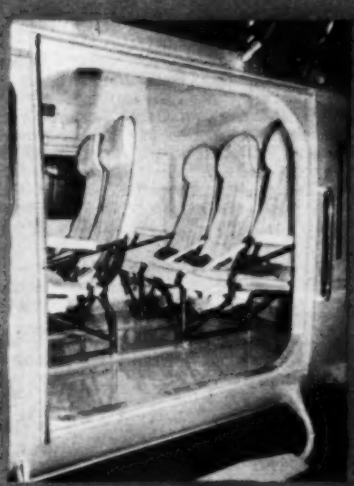

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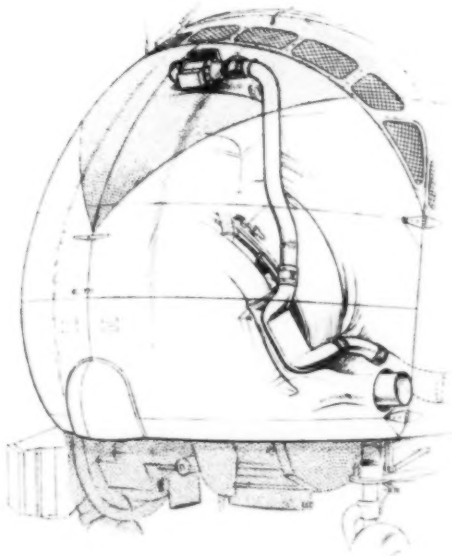

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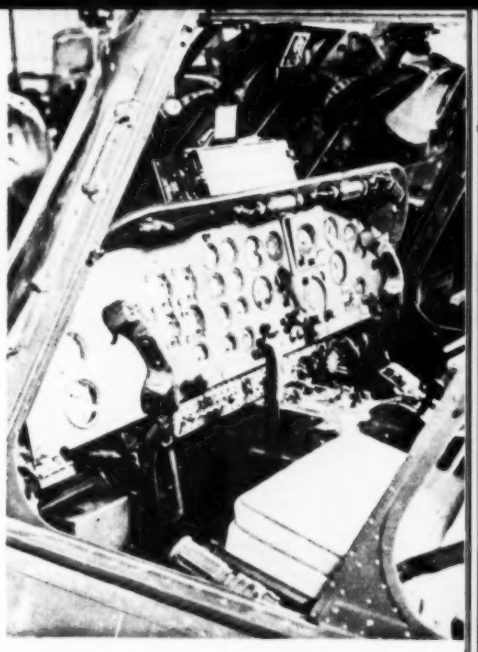

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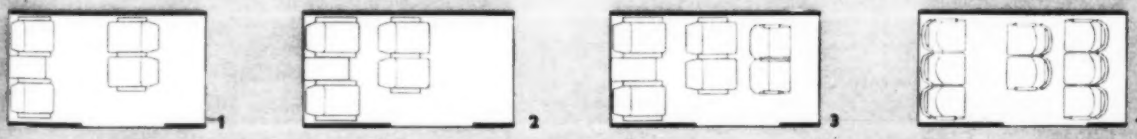

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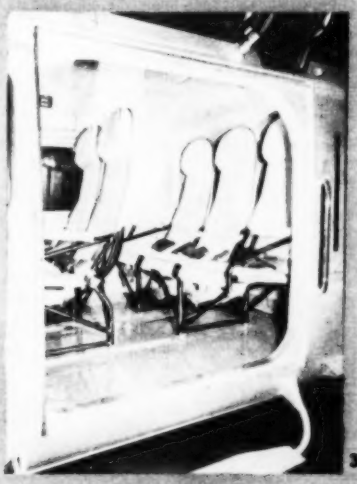


Sport and Business

Interest in this country in the possibilities of manpowered flight has recently re-awakened, with the formation of the Royal Aeronautical Society's Manpowered Aircraft Group (the inaugural meeting of which is reported on page 486). Two current projects in this field, as described in last week's issue, are Emiel Hartman's ornithopter (above) and the inflatable fixed-wing aircraft designed and built by Daniel Perkins of R.A.E. (right). The wings of Hartman's machine are flapped by arms-and-legs rowing action by the pilot (whose handgrips are used also for rudder and elevator control); the pusher propeller of Perkins' aircraft has yet to be fitted

WINNERS OF THE LONDON - PARIS RACE organized by the *Daily Mail* last June to mark the 50th anniversary of Bleriot's cross-Channel flight were guests of honour at a Royal Aero Club dinner on Tuesday, October 27. Also included among the guests were Maj. Jacques Allez, president of the French Aero Club, and Arthur Wareham, editor of the *Daily Mail*. G/C. Norman Ryder, captain of the R.A.F. entry, gave an account of his team's preparations for the race, and said that the Service had gained much useful information on the low-level operation of Hunters and on emergency stops for helicopters—in addition to the new experience of being carried at 85 m.p.h. on a motor-cycle pillion through Paris. The new operational information was already being used by the instructors at the Central Fighter Establishment.

Other speakers at the dinner included Col. C. F. H. Gough, chairman of the club; W/C. Charles Maughan, winner of the race; Mr. Wareham; and Eric Rylands, runner-up and fastest civilian competitor, who paid a tribute to the "most magnificent navigation and flying I ever hope to see" by his Hunter pilot, Bill Bedford of Hawker Aircraft. Mr. Rylands had gained "more fun, more friends and more new swearwords" from the race, and he hoped that the newspaper would sponsor a transatlantic race in 1969 to commemorate the 50th anniversary of the first direct Atlantic crossing by air.

Top table at the Royal Aero Club on October 27: from the left, W/C. Charles Maughan, Col. C. F. H. Gough, Arthur Wareham, G/C. Norman Ryder and Eric Rylands. The occasion, reported above, was the House Dinner in honour of the winners of the "Daily Mail" Blériot Anniversary Race

GUEST OF HONOUR at the annual dinner of the Surrey and Kent Flying Club, held in Croydon on Friday, October 30, was Mr. C. M. Colbeck, South Eastern Divisional Controller of the Ministry of Aviation. Other speakers at the dinner were Mr. Duncan Lush, deputizing for the president of the club, Dr. A. P. Thurston; and club chairman Ken Freeman. Among the winners of Club trophies were Tony Wilcox (Thurston Trophy for the best pupil of the year) and J. Crouch (Harris Trophy for navigation).

Deliveries of the new Piper Aztec—a five-seat, $49,500 aircraft with a cruising speed of 205 m.p.h.—are scheduled to begin next month. The powerplants are two 250 h.p. Lycomings, and the aircraft is claimed to have the highest single-engine service ceiling (7,400ft at full load) of any aircraft in its class with a comparable payload (further details in news item on this page)

A PORTRAIT of W/C. C. E. F. Arthur, C.F.I. at Fair Oaks Aero Club, was being presented to him yesterday (November 5) at the conclusion of the first 1959-60 night-flying session and to the accompaniment of suitable Guy Fawkes' Night celebrations. The portrait has been painted (from a photograph) by Miss Pamela Till; and the presentation was being made by Ron Cobbett, senior flying instructor. "Wingco" Arthur has been at Fair Oaks since 1937, commanding No. 18 E.F.T.S. there during the war.

AT THE STEERING WHEEL CLUB on Monday, October 19 (the anniversary of the Moroccan Grand Prix), Mike's Mug, the tankard that was to have been presented by the Steering Wheel Club to Mike Hawthorn, was handed over by racing driver Jack Brabham to A. Cdre. A. H. Wheeler, representing the Royal Aero Club.

The tankard symbolizes the common enthusiasm of those who drive motor cars, and fly aeroplanes, for sport. Hawthorn, who owned an Argus and later a Vega Gull, used his aircraft both for sport and for business travel, and the Royal Aero Club is to award the tankard to the pilot who, in the Club's opinion, has demonstrated most convincingly "the utility of a light aircraft for business and executive as well as private purposes."

In return the Royal Aero Club presented to Mr. John Morgan of the Steering Wheel Club a menu signed by Mike Hawthorn at the dinner given by the R.Ae.C. in his honour after he had won the World Racing Drivers' Championship.

DEVELOPED FROM THE APACHE, the new Piper Aztec employs many systems and components of the Apache but is radically different in external appearance and cabin design. The tail unit incorporates a swept fin and rudder and "single-piece stabilator" fitted with a wide-span anti-servo tab. A further difference from the Apache is in the two additional windows located abreast of the fifth rear seat. The two forward and two centre seats are reclinable in three positions.

With an empty weight of 2,775 lb and maximum gross weight of 4,800 lb—an increase of 1,000 lb over the Apache—the Aztec payload is sufficient for five 170 lb passengers, 144 gal of fuel, oil, and 247 lb available for radio and baggage. Fuel is carried in four 36-gal rubber cells within the wings, outboard of the two six-cylinder, 250 h.p. Lycoming O-540 direct-drive engines.

Performance figures for the Aztec include top speed 215 m.p.h., cruising speed (75 per cent power at 7,000ft) 205 m.p.h.,

RETROSPECT

From "Flight" of November 6, 1909

A Note of Interrogation: Some curiosity has been expressed by several readers as to the meaning of the note of interrogation after the word "Aero-Naph" in the Anglo-American Oil Co.'s advertisement last week. We find upon inquiry that it has no particular significance. It is merely the result of an accidental touch of one of the keys by the advertisement typewriter, which passed unnoticed by the clerk. There are no queries about Aero-Naph—it is a certainty.

Sport and Business . . .

(65 per cent power at 9,000ft) 200 m.p.h., stalling speed 62 m.p.h., take-off run 750ft, landing run 900ft, absolute ceiling 23,750ft, range 1,025 miles at 75 per cent power, 1,200 miles at 65 per cent power, 1,400 miles at 45 per cent power.

A RECORD FLYING-TIME TOTAL for 1958-59 was announced at the annual general meeting of Exeter Aero Club on October 28. The figure was 3,387 hr, an increase of almost 1,000 hr compared with the previous year's total. The parent company, Exeter Aero Club Ltd., has recently been acquired by Harper Engineering & Electronics Ltd., but no change in the operations of the club is planned. The club committee for the forthcoming year comprises D. H. King, chairman; R. W. Innalls, vice-chairman; and Miss S. Savory, P. Morgan, J. Stewart, H. Williams, Mrs. S. Swithinbank, and R. Daw.

PROTOTYPE OF THE BEECHCRAFT MODEL 33, a single-engined four-seat business aircraft, made its first flights recently at Wichita. Similar to the Bonanza but with a conventional tailplane and swept fin and rudder, the new machine is powered by a 225 h.p. Continental with fuel injection, and is expected to sell for about $20,000.

HANDLING THE OMNIPOL MORAVA

BY MARK LAMBERT

An ample five-seat cabin, two Walter M-337 engines, a cruising speed of 173 m.p.h. and excellent handling characteristics are features of the Czechoslovak Morava

SEVERAL Czechoslovak aircraft have now been demonstrated in this country, and one or two have been imported; and from experience of various types it is evident that the Czech designers know their job well and can produce excellent and economical aircraft. Their latest product, the L.200 Morava light twin, is about to go into full production in Czechoslovakia and will not be seen in England until next year, but I took the opportunity of flying it during a recent visit to France and was able to prepare this exclusive report. Many Super Aeros have been sold, and it looks as though this new type will be similarly successful. The British agent for Omnipol, incidentally, is G/C. Edward Mole, 3 Red Place, Green Street, London, W.1.

The Morava is unquestionably a most creditable effort. The cockpit layout is well thought out and the controls are logical and well marked. There seems to be more than enough room for five occupants in well-padded seats, with room remaining for a very big luggage compartment behind the cabin. The aircraft generally is stoutly built and easy to handle, and yet cruises fast and has very good single-engined performance. I feel that it looks rather chunky, but others do not agree.

Before climbing in to fly the Morava with the Czechoslovak demonstration pilot, L. Skala, I took a look round the airframe. The aircraft sits low and level on the ground, and its all-metal structure is flush riveted on all forward-facing surfaces. Most of the fuel—that is, 50 Imp. gal—is divided between fixed tip-tanks, with another 41 Imp. gal distributed in two tanks in the wing roots. Aileron, flap, elevator and rudder skins are stiffened by fluting, and the flaps run rearwards and downwards on buried rails to a maximum extension of 30 deg. The flaps and undercarriage are hydraulically extended by power from engine-driven hydraulic pumps, or by a stand-by hand-operated pump. Independently controlled wheel-brakes are also hydraulic, and the mainwheels have a tough, levered oleo suspension which gives an excellent ride on rough ground. A long dorsal strake has been added along the top of the fuselage. Trim tabs are provided for elevator and rudder, and the ailerons are of the unslotted Frise type.

A square hatch at waist level in the port side of the fuselage gives access to the baggage compartment, which is fitted with an interior light and built-in tie-down straps and can take up to 176 lb of baggage. Hand luggage can also be stowed on a wide shelf behind the rear bench seat. Access to the main cabin, level with the front seats, is by exceptionally large car-type doors on either side. They extend well into the roof, so that one can practically stand up in a front seat without stunning oneself. The backrests of the front seats fold down and the seats themselves slide right forward to make access to the three-place rear bench easy.

The engines are of the new Walter M-337 type, which is an exact six-cylinder equivalent to the four-cylinder M-332, that is, they have a direct-injection fuel system, and a supercharger which can be engaged to increase maximum power from 180 h.p. to 210 h.p. The M-337 has an augmenter exhaust system. The two-blade metal propellers on this first prototype were like those of the Super Aero. Take-off, climb and cruising pitch settings could be selected by an electric switch, and fine adjustments made with press-button inching controls. A fourth setting feathered the propellers, but it is intended that production Moravas shall have true constant-speed propellers controlled from levers next to the throttles. Use of the supercharger below 5,000ft is limited to five minutes, but above this height it can be continually engaged to restore the maximum continuous boost setting of 66 mm Hg, and the Morava can then cruise at a T.A.S. of 180 m.p.h., and a fuel consumption of just over 13 gal/hr.

In the cockpit were a full blind-flying panel and a comprehensive set of engine instruments with engine controls grouped on a quadrant in the centre of the panel. The hand pump and selector for emergency hydraulics were between the seats, together with the parking-brake catch and the trim wheels. Because it was tucked away on the floor between other controls, the elevator trim wheel was difficult to manipulate, but this shortcoming is to be rectified in production aircraft. Most electrical switches were conveniently grouped in the form of circuit-breakers shaped like modern typewriter keys. Separate keys had to be depressed to activate the electrical system (master switch), generator, battery, propeller control, instruments and engine instruments.

Engine starting followed standard procedure, and we rolled out to the take-off point using nosewheel steering. Full power at take-off produced 2,750 r.p.m. and 86 mm boost and, after a short run, Skala flew the Morava off at about 95 km/hr (59 m.p.h.), producing a very respectable 1,380ft/min rate of climb. There were three occupants, and in each tip-tank was about 11 gal of fuel.

At 1,700m (5,500ft) we levelled off, set 2,400 r.p.m. and 66 mm

The very large access doors on both sides of the cabin, left, are an admirable feature of the Morava, but leave a rather wide windscreen pillar. At right, the tough, levered-suspension main undercarriage units keep the Morava low and level on the ground. The nosewheel is steerable

HANDLING THE OMNIPOL MORAVA . . .

and achieved a true airspeed of 174 m.p.h. Visibility forwards, sideways and rearwards was exceptionally good, a small window in the rear of the cabin roof providing a clear view down the top of the rear fuselage. In turns, however, visibility was somewhat obscured by the rather broad, curving door pillars. The engines produced a distinctive, deep note which I found rather insistent. After a considerable amount of hard test flying the door on my side no longer fitted very closely and let in some annoying draughts. Because this was a hand-made prototype the condition was not surprising, but one felt that it was a point that will have to be watched in production machines. There may be some penalty to pay for so large a door, in every other respect an admirable feature.

General handling at about 170 m.p.h. was remarkably pleasant. The Morava felt almost as steady as an airliner, yet control was crisp and well harmonized, and a high rate of roll could be achieved. Little rudder was needed to co-ordinate a sharp reversal of direction of turn, and longitudinal stability felt very good.

Having got the feel of the Morava in cruising flight, we cut and feathered one engine and, at about 100 m.p.h., achieved between 200 and 300ft/min rates of climb at something over 2,000ft. In this condition the aircraft handled extremely well and required very little trimming and no high control forces. There was nothing difficult in feathering or unfeathering, the whole operation being straightforward.

We next tried stalls, starting with both engines running and undercarriage and flaps up. Speed dropped off steadily and all the controls remained fully responsive until a gentle stall came with very little warning at about 62 m.p.h. There seemed to be practically no tendency for a wing to drop, and recovery was immediate on releasing the controls. I tried another stall with undercarriage and flap down. This time there was noticeable buffeting before the Morava stalled at 59 m.p.h. I held the control wheel hard back in the stall and maintained a good measure of control, although one wing dropped gently. The altimeter registered only 100m (328ft) of height lost. A three-to-one ratio of cruising to stalling speed is, I feel, a respectable achievement for a fast five-seater twin.

We had now been airborne for about 25 minutes, and I returned to land from the right-hand seat in a left-hand circuit. Standard approach speed was 87 m.p.h., which was easy to hold accurately, and extension of flap and undercarriage produced only small trim-changes. I suspect that the glide angle with the engines throttled back is a trifle shallow. At the lower power settings the throttle levers moved more or less vertically, a rather awkward effect in comparison with fore-and-aft motion. The flat, aerofoil-shaped flap lever had to be pulled out before it could be moved and returned to neutral as soon as the required flap angle was reached; this made selection a little uncertain from the right seat. Visibility on the approach was excellent and the angle of attack perfectly normal. Power could be cut during round-out without causing a sudden sink, and the Morava could be accurately positioned during the ensuing float. The nosewheel went down gently, steering was immediately available, and the brakes were good and powerful. I put the aircraft down fairly roughly, but the levered suspension comfortably absorbed the shock.

From this half-hour flight my general impression was that the Morava has been carefully and intelligently designed and is docile, pleasant to fly, fast and well suited to grass-field operation. It has been reported that Omnipol are keen to sell Moravas to Aeroflot to supplement or replace the large number of Super Aeros which they are still in course of supplying. I cannot think that they will have any difficulty in demonstrating to the Russians, or to anyone else, that the Morava is a thoroughly worthwhile aeroplane.

An interesting feature in the cockpit, incidentally, was a Czechoslovakian V.H.F. radio which included seven crystal-controlled receiver channels and a transmitter hand-tunable between 110 and 130 Mc/s. Receiver and transmitter could be synchronized by pressing a button and hand-tuning to an aural null. Earlier automatic "whistle-stop" tuning had been replaced by the manual system because it was found that it did not always achieve sufficiently accurate synchronization.

Omnipol L.200 Morava

(Two Walter M-337 each giving 180 h.p. without and 210 h.p. with supercharger engaged)

Span, 39ft 4¼in; length, 28ft 2¼in; wing area, 186 sq ft; empty weight, 2,645 lb; maximum gross weight, 4,232 lb; useful load, 1,543 lb; max. speed, 192 m.p.h.; cruising speed, 173 m.p.h.; twin-engined ceiling, 21,650ft; take-off run, 721ft; take-off distance to 50ft, 1,800ft; landing run, 820ft; range at nominal power at 6,500ft, 1,050 miles; fuel consumption at nominal power, 16.5 Imp. gal/hr.

ROTORS OVER THE MOTORWAY

APART from its value as a navigation check for the amateur pilot, the London - Birmingham motorway (officially opened last Monday, November 2) has other links with aviation: helicopters were employed for communication work during its construction, and in use it will be patrolled by the Automobile Association's aircraft as and when necessary.

A finely produced and absorbingly interesting commemorative brochure, written by L. T. C. Rolt and published by the motorway contractors, John Laing & Sons Ltd., pays tribute to the utility of the helicopters, a Sycamore chartered from Bristol Aircraft and a Whirlwind from B.E.A. The first flight, in the Sycamore, showed that it was possible to obtain a comprehensive low-level view of the whole motorway in ninety minutes. "But," says Mr. Rolt, writing of the helicopter as a type, "that versatile machine soon showed that it had a much wider sphere of usefulness. There was room on board if necessary for project or sub-project managers so that a particular problem could be speedily examined and discussed on the spot. An internal mail service was operated up and down the route. An emergency casualty service to local hospitals was arranged, though happily such casualties were extremely rare. In the case of mechanical casualties, urgently needed spare parts could be flown up from the company's plant depot at Elstree. Last, but by no means least, among the advantages of the helicopter was that, like the system of radio communication but in a still more personal way, it helped to bind the men on the job into one enthusiastic and harmonious team. No one could feel that he was 'out on a limb.'

"The enthusiasm, that sense of being a member of a team which was making history, quickly infected successive pilots of the helicopter. They were not members of the company's staff, yet so keenly did they follow the progress of the work that when visitors were privileged to fly with them over the motorway they would voluntarily deliver an accurate and detailed running commentary over the intercom."

BASIC BALLISTICS

CONSIDERATIONS OF TRAJECTORY AND RE-ENTRY

By J. A. H. BAILIE*

IN many parts of the world a vast amount of money and energy is being spent in the development of a horde of missiles, intended to be fired from land, sea and air. They differ in take-off weights from a few pounds to a few hundred tons, and in their propulsion, guidance and control systems as well as in the targets against which they are fired. It has been found that, when seeking to destroy fixed targets at global range, the so called "ballistic" missile has great advantages over any whose flight remains within the earth's atmosphere. In particular, it is much more difficult to intercept.

The basic reasoning behind the ballistic missile is that above the atmosphere aerodynamic loads are zero, and the only forces are those due to thrust, the earth's gravitational field and those applied during manœuvring. Since rocket thrust increases with increasing altitude—reaching a maximum in a vacuum—it is at least intuitively attractive to study the possibility of covering most of the journey outside the atmosphere. This is what is done, and most ballistic missiles reach peak altitude of the order of a few hundred miles for optimum performance.

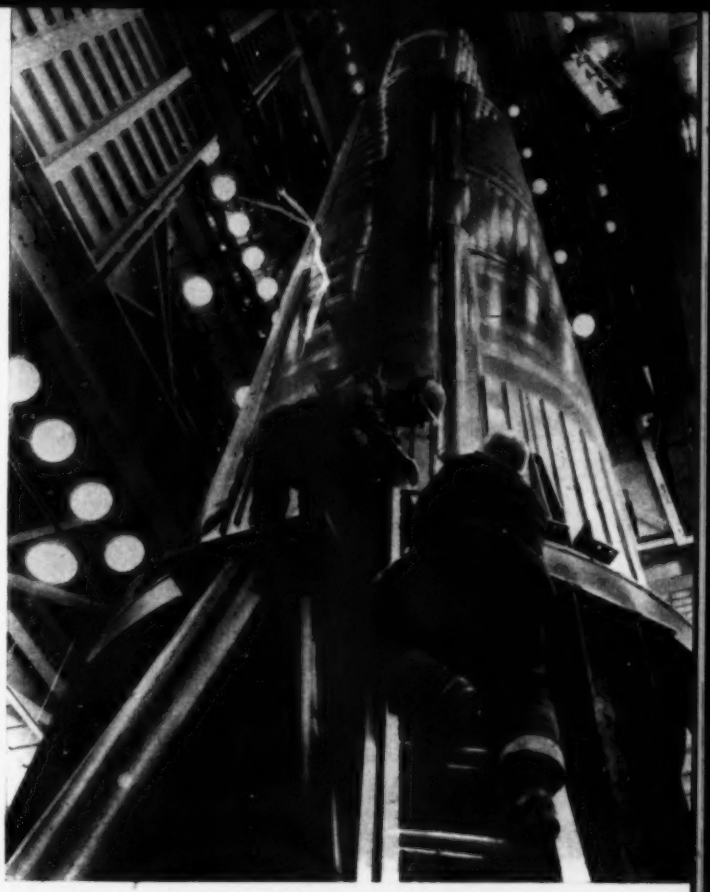
We can consider a mission in three separate stages, two taking place mostly within the atmosphere and the other outside it. The first is powered flight, during which the rocket engine accelerates the missile to the desired speed and altitude and the controls orient it in the required direction. The second part is that in which the ballistic trajectory is followed; the missile is in a vacuum and the earth's gravitational force causes it to follow an elliptical path until it again reaches the edges of the earth's atmosphere. Here the third portion of the flight begins; aerodynamic forces rotate the vehicle so that the nosecone points in the desired direction (which is different from that assumed when leaving the atmosphere).

Powered Flight. Soon after launching, the directional controls become effective and pitch the vehicle over slightly in the direction of the target. Although the effect of drag on range is small it is naturally kept to a minimum, and the elimination of induced drag (drag due to lift) is an advantage. If the trajectory is such that the longitudinal axis always remains parallel to the direction of motion then aerodynamic lift is zero. Moreover, the thrust vector will be in the same direction (if the small components perpendicular to the longitudinal axis necessary for correcting the trajectory are neglected) and the work done by the motor in accelerating the vehicle along its flight path ($\int$ TV dt) is a maximum.

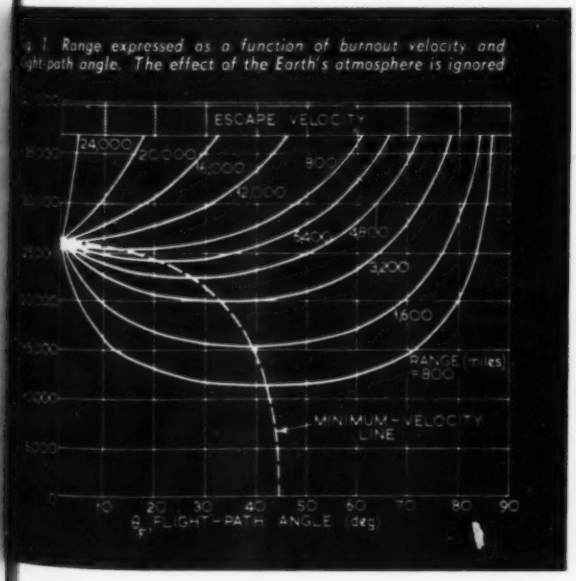
Under this condition gravity forces will cause the vehicle path to bend steadily towards the horizontal, and the trajectory is known as a "gravity turn." Since such a manœuvre minimizes both aerodynamic drag and aerodynamic heating, it can be taken as being optimum way of leaving the atmosphere and it is usually used. The range of a projectile given an initial velocity at a specified angle to the horizontal is the basic problem of the ballistic trajectory outside the earth's atmosphere. Thus the objective of the powered phase is simply to position the missile in space with the required velocity so that it will arrive at its target. For final accuracy the re-entry phase is obviously vital, but the range covered during re-entry is small.

Range in a vacuum as a function of burnout velocity and flight-path angle is shown in Fig. 1, taken from Ref. 1. By burnout velocity is meant the velocity at which all the fuel is used up or the motor is switched off. There are an infinite number of combinations of velocity, angle and altitude that will yield the required range (if the vehicle is capable of attaining them). The problem is to discover which is the optimum, i.e. that yielding the greatest range with a given payload for the minimum burnout velocity. Normally this leads to minimum propellant and launch weights. Range for a given optimum burnout condition is shown in Fig. 2, taken from Ref. 2. This curve shows two features of great significance. First, the range of a ballistic vehicle is critically dependent on burnout velocity. Second, burnout altitude is relatively unimportant, provided it is outside the atmosphere.

In a discussion of such a subject it is essential to talk in general terms, but it seems desirable at the same time to carry out the design of a hypothetical ballistic missile. This will be an aid to showing the orders of magnitude of the significant parameters necessary to accomplish a prescribed mission. Suppose we want to deliver a payload† of 1,000 lb over a range of 5,000 miles. Neglecting the range covered during powered flight and re-entry



The mighty Titan ICBM, here seen in Martin's Denver plant, is an outstanding example of the "series" system of staging discussed overleaf



g. 1. Range expressed as a function of burnout velocity and ight-path angle. The effect of the Earth's atmosphere is ignored

**Member of the technical staff, Lockheed Aircraft Corporation, Missiles and Space Division, Sunnyvale, California.*

†*By payload is meant the weight of the bomb and attendant structure, generally called the re-entry body.*

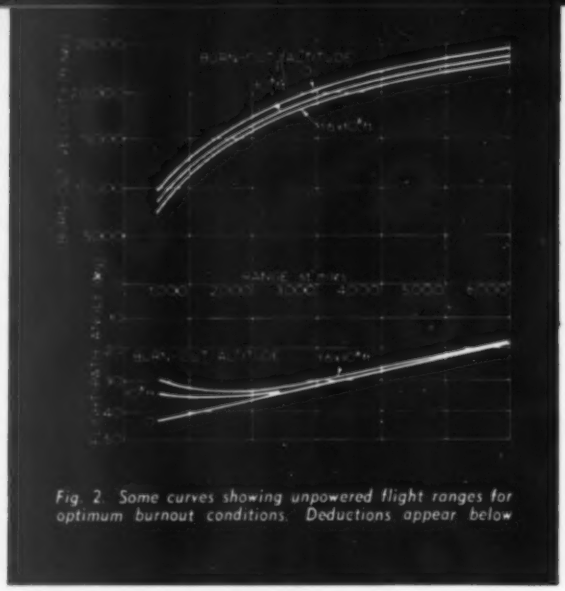


Fig. 2. Some curves showing unpowered flight ranges for optimum burnout conditions. Deductions appear below

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(they will be shown later to be small) Fig. 2 shows that by some means the payload must be accelerated up to approximately 22,000ft/sec (15,000 m.p.h.) at about 1,000,000ft (190 miles) altitude, and be given a flight-path angle of roughly 23 deg. The burnout velocities required for long-range ballistic and satellite flights have been known for a long time, but it is only in the past few years that prodigious advances in engineering have made such flights possible.

In this paper it is assumed that only chemical rockets will be used, and it is necessary to introduce a few vital parameters by which their performance may be judged. Ref. 2 shows that only three vehicle design parameters are needed to non-dimensionalize the trajectories. The parameters are specific impulse, ratio of initial to final weight and initial axial load-factor. The reference provides the required non-dimensional curves from which the complete time-history of the trajectory can be found.

If we neglect drag and the component of the weight, the equation of motion along the longitudinal axis of the vehicle is

$$\frac{W}{g}\frac{dV}{dt} = -F = -F\frac{\frac{dW}{dt}}{\frac{dW}{dt}} = -I\frac{dW}{dt} \qquad (1)$$

where W is weight (lb); g is acceleration due to gravity (ft/sec^2); F is thrust (lb) and the minus sign is because the weight is decreasing with respect to time. I is specific impulse, thrust divided by fuel consumption—clearly an important parameter, since it is a measure of the use made by the rocket of each pound of fuel.

Solving (1) for a single-stage rocket starting from rest shows that burnout velocity v_f is given by

$$v_f = Ig\log_e\frac{W_i}{W_f} = C\log_e\frac{W_i}{W_f} \qquad (2)$$

where W_i is launch weight and W_f the burnout weight (payload plus structure, fuel tanks, engine and guidance). C is known as the effective jet velocity. Solving (2) for W_i/W_f gives

$$\frac{W_i}{W_f} = e^{v_f/Ig} = e^{v_f/C} \qquad (3)$$

where e is the base of natural logarithms. Accepting the fact that 250 is a very good specific impulse for present-day chemical rockets; then to get the required burnout velocity

$$\frac{W_i}{W_f} = e^{2\cdot 73} \simeq 15.3$$

A reasonable assumption about W_f is that one quarter of it is payload, and the rest is made up from motor cases, fuel tanks, and so forth. Therefore, to carry the 1,000 lb payload over 5,000 miles, the launch weight of the vehicle cannot be less than 61,200 lb (and we have neglected aerodynamic drag and gravity). It is worth noting that the computations outlined are blissfully linear. If we double the payload we do likewise to the take-off weight. Another interesting point is that propellants (fuel and oxidant) make up about 14/15 of 93.4 per cent of the launch weight.

Next step in the design is to choose a motor with adequate thrust. Suppose there is available an engine with a thrust of 120,000 lb (and assume this figure to be independent of altitude, although actually rocket thrust increases with altitude and reaches a maximum in a vacuum). Knowing the take-off weight and thrust, the axial load factor at launch is fixed (2.0 in our example), and the

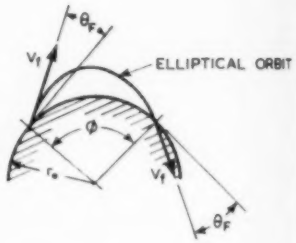
trajectory during powered flight can be computed using Ref. 2. Burnout occurs 119 sec after leaving the ground, at a height of 360,000ft (68 miles) and a range of 108 miles (2 per cent of the required range). This justifies our initial assumption that the increment of range obtained during powered flight is negligible for relatively long ranges—although as the overall range decreases it becomes more important. Aerodynamic drag and the effects of altitude on thrust have been accounted for in Ref. 2 by corrections to the specific impulse and initial axial load factor. For our example these means that the specific impulse assumed is 3 per cent too large; but this difference can be ignored and the trajectory computations are adequate for initial design purposes.

From the definition of specific impulse it is seen that the propellant consumption is thrust divided by specific impulse; in this particular case it is 480 lb/sec, which is high compared with more conventional propulsion devices. Since the mass of the vehicle decreases at this rate, the increase in longitudinal acceleration is rapid. In our vehicle it rises from 2g to almost 30g at burnout. This underlines why it is permissible to neglect the component of gravity along the thrust-axis in the initial design trajectories.

Multi-stage Rockets. The rapid increase in acceleration as the weight decreases suggests a significant way of increasing the burnout velocity, and hence range. As the propellants are burnt, the structure used to contain them becomes so much dead weight. Clearly, performance can be improved if we divide the fuel space into a number of smaller tanks and throw each away as it becomes empty. This is the idea behind multi-stage rockets. With liquid systems, it is usually not only the fuel tanks that are discarded, but the motors they feed as well. With solid propellants the motor and tank structure are the same items.

There are basically two methods of staging rocket vehicles: the series system and the parallel system. Series systems seem to be the most common. The vehicle consists of a number of self-contained propulsion systems mounted one on top of the other. The lowest rocket fires first and propels the vehicle until its fuel is exhausted. It then separates and falls away, and the second stage takes over the job of propulsion; and the procedure is repeated as each stage burns out. The parallel system involves a cluster of rockets, all of which fire at launching. Acceleration during the early part of the flight is more rapid than with the series system, as a result of increased fuel consumption and thrust. At a certain stage it becomes advantageous to throw away a number of the motors, to reduce the weight to be accelerated by those remaining. With liquid motors it is possible to cluster the individual tanks around the vehicle and jettison them with the motors; but the increased complexity of detail design in such systems seems to override their advantages.

The diagram on the right illustrates the basic principles of the trajectory of a ballistic missile. The Earth is shown shaded and the missile is assumed to be flying throughout in a vacuum; in practice the trajectory is modified by the presence of the atmosphere



RANGE = $r_o\,\phi$
V_f = BURN-OUT VELOCITY
r_o = EARTH'S RADIUS

For the huge vehicles needed to perform space missions this may not be the case. To obtain a feel of the advantages of multi-stage vehicles, it is useful to carry out a simplified analysis based on Ref. 3. It has been shown that the increase in velocity during the firing of a single-stage motor is:

$$\Delta v_k = I_k g\log_e\left(\frac{W_i}{W_f}\right)_k$$

where subscript k denotes the k^{th} stage. Assuming the same specific impulse for each of N stages, the velocity at the end of the N^{th} stage is

$$\left(v_f\right)_N = Ig\log_e\left(\frac{W_i}{W_f}\right)_1 \cdots\cdots \left(\frac{W_i}{W_f}\right)_N \qquad (4)$$

Without going through the detailed design of a particular vehicle it is difficult to compute how much weight is jettisoned at the end of each stage. The assumption of Ref. 3 is that the weight jettisoned at the end of each stage consists of a motor and tank

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structure whose weight is a fixed proportion of the initial weight of that stage.

$$\left(W_f\right)_k - \left(W_i\right)_{k+1} = K\left(W_i\right)_k \qquad (5)$$

This is certainly a reasonable assumption for a series-staged vehicle, although it is possible to make a number of others. Substituting (5) into (4) yields the equation for the burnout velocity of the final stage of this type of vehicle.

Optimizing it to give a maximum final burnout velocity, for a given ratio of launch weight to payload, shows that the weight ratios of each stage should be equal. Therefore

$$\frac{(W_i)_1}{(W_i)_2} = \frac{(W_i)_2}{(W_i)_3} = \ldots\ldots = \frac{(W_i)_N}{W_p}$$

Where W_p is payload weight, and launch weight divided by payload $= [(W_i)_N/W_p]^N$. Hence

$$(v_f)_N = Ig\log_e\left[\frac{(W_i)_N}{K(W_i)_N + W_p}\right]^N = Ig\log_e\frac{(W_i)_1/W_p}{[1+K\{(W_i)_1/W_p\}^{1/N}]^N} \qquad (6)$$

Equation (6) is plotted in Fig. 3, to emphasize the great advantages of multi-stage vehicles. It must be remembered that the curves are for a particular value of weight jettisoned at each stage, and that constant specific impulse of 250 is assumed.

The most significant point about Fig. 3 is that, as the number of stages is increased from one to two, the ratio of take-off weight to payload required to enable the payload to reach a given velocity at burnout decreases greatly. The gain in going from two to three stages, or more, is not nearly so great, but several stages are sometimes used to extract the maximum performance from existing rocket motors. The smaller the value of K, the more efficient is the structure and component design, and Fig. 3 shows the great importance of this. A value for K of 0.05 is probably a little optimistic at present. Another point of interest is that multi-staging offers little, if any, advantage for burnout velocities below about 13,000ft/sec and ranges less than 1,000 miles if the weight distribution is as assumed. In spite of all the simplifying assumptions, Fig. 3 certainly illustrates the general trend.

Now let us consider parallel staging. At the end of each stage a number of motors, and their equipment, fall away, reducing the mass to be accelerated by those remaining. As an example, consider a two-stage vehicle with launch weight and thrust of 50,000 and 100,000 lb, respectively, and with a fuel consumption of 500 lb/sec during the first stage, which lasts 40 seconds. If the weight of motors, structure and equipment jettisoned is 2,000 lb then the incremental weight of the first stage is 22,000 lb (fuel+"dead" weight). Assuming that the weight jettisoned is a constant fraction of the difference between initial weights of the two stages, the jettisoned weight at each can be written

$$\Delta W_i = (W_f)_k - (W_i)_{k+1} = K[(W_i)_k - (W_i)_{k+1}] \qquad (7)$$

For our example, (7) becomes

$$\Delta W_1 = 2{,}000 = K[50{,}000 - 28{,}000] \quad \therefore \quad K = .091$$

If we assume the same value of K for all stages of an N-stage vehicle, it can be shown that the velocity at burnout of the final stage, for optimum weights of the stages, is

$$\left(v_f\right)_N = Ig\log_e\frac{(W_i)_1/W_p}{[1-K+K\{(W_i)_1/W_p\}^{1/N}]^N} \qquad (8)$$

comparing equations (7) and (8) it is seen that the parallel system is slightly superior, in that the final velocity—which determines range—is greater for a given ratio of launch weight to payload. Equation (8) is shown in Fig. 4 for a typical range of parameters.

Returning to the first example of 1,000 lb payload (burnout weight 4,000 lb) over 5,000 miles, the decrease in take-off weight due to multi-staging is remarkable. Assuming $K=0.05$, the single-stage weight of 80,000 lb is reduced to 23,000 lb for a two-stage "series" vehicle and 20,500 lb for a two-stage "parallel." The weight ratios are obtained by taking the intersection of the "$(v_f)_N$=22,000ft/sec" line in Figs. 4 and 5. These figures also show how vitally important is the reduction of structural and component weight. If K is increased from 0.05 to 0.10 the launch weights for the two-stage vehicles increase to 41,000 and 34,000 lb, respectively. It is important to appreciate that this indicated superiority of parallel staging holds for the assumption about the weight jettisoned and the assumption of equal values of K for both systems. Different assumptions about jettisoned weight can show the series vehicle to be superior for many practical and desirable designs. In addition, even using our assumption about jettisoned weight, the balance in favour of one system may be decided by a difference in K actually attainable.

Unpowered Flight. Having achieved the desired burnout conditions, the vehicle follows its elliptical path through the vacuum of space, acted upon only by the Earth's gravity and centrifugal accelerations. From the point of view of trajectory it is unimportant whether the dead weight of the final stage is jettisoned or not, since both it and the payload have been accelerated to the desired speed and oriented at the correct angle. However, the temperatures generated on re-entry to the atmosphere destroy ordinary materials, and so it is general practice to separate the last rocket stage from the payload and allow it to burn up on re-entry.

During re-entry the nose of the vehicle needs special protection from the heat generated. If there is any possibility of the vehicle being aerodynamically stable when flying backwards, it is vital to prevent it from tumbling over and over in space. Tumbling may be caused by an imperfect separation; such a separation does not occur all round the connection instantaneously, and the ensuing moments produce undesirable deviations in the trajectory.

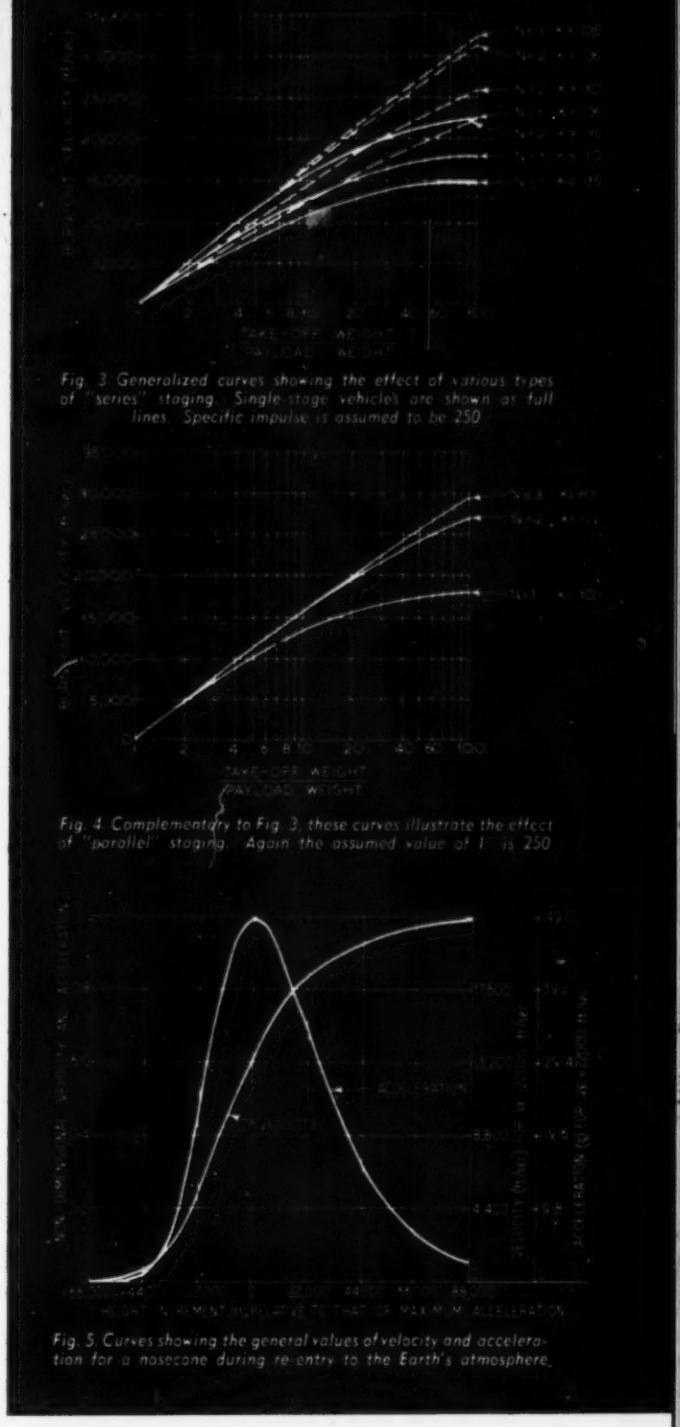

Fig. 3. Generalized curves showing the effect of various types of "series" staging. Single-stage vehicles are shown as full lines. Specific impulse is assumed to be 250

Fig. 4. Complementary to Fig. 3, these curves illustrate the effect of "parallel" staging. Again the assumed value of I is 250

Fig. 5. Curves showing the general values of velocity and acceleration for a nosecone during re-entry to the Earth's atmosphere.

Above, workers in General Electric's Missile and Space Vehicle Department are inspecting a Mk 2 heat-sink nosecone. A 1,115 lb copper slab, it has a nose radius of 14.94in, and for the Atlas ICBM has a nickel-plate surface polished to a finish of 12 micro-inches. It is now being replaced by the lighter and faster-flying Mk 3 cone (left) which is shown in the drawing of Atlas on page 508

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A method of preventing such tumbling is to spin the vehicle about its longitudinal axis so that the resultant gyroscopic forces maintain the desired angle. In a well-stabilized trajectory the angle of attack of the vehicle does not change outside the atmosphere. It follows the elliptic trajectory, and reaches a maximum altitude of the order of 2×10^4ft (380 miles) for a typical long-range ballistic missile.

Re-entry. The density of the atmosphere fades out relatively gradually, so that it is not possible to define the exact instant at which a vehicle re-enters. Experience seems to suggest that for our purpose one can neglect the effect of that part of the atmosphere above roughly 250,000ft (≏50 miles). When the nosecone reaches this height on the descent it is travelling very slightly faster than at burnout, since it is lower than burnout height. The vital question "What happens to a re-entering vehicle?" is best answered by studying the work of Allen and Eggers, and in particular Ref. 4. The problem will be broken down into two parts. We first study the motion involved and then apply the resulting information to a study of the aerodynamic heating of the re-entry body.

From Ref. 4, the equations for velocity and acceleration are, neglecting gravity

$$V = V_E e^{-\frac{C_D \varrho_0 A}{2\beta m \sin\theta_E} e^{-\beta y}} \qquad (9)$$

$$-\frac{dV}{dt} = \frac{C_D \varrho_0 A V_E^2}{2mg} e^{-\beta y} e^{-\frac{C_D \varrho_0 A}{\beta m \sin\theta_E} e^{-\beta y}} \qquad (10)$$

where V_E is the entry velocity; β is 1/22,000ft^{-1} and is the constant in the expression for density (i.e., $\varrho = 0.0034\, e^{-y/22,000}$); y is the height; m is the mass of the body; and θ_E is the re-entry angle. The other symbols have their usual aeronautical meanings.

One of the basic assumptions of (9) and (10) is that the drag coefficient is constant. This may at first seem strange, but for the very high speeds involved it is an entirely adequate assumption for a comparative analysis of this type. The neglect of gravity is justified since deceleration due to aerodynamic drag is relatively large. This means that the re-entry trajectory is virtually a straight line, and the re-entry angle is maintained throughout. A significant point about (10) is that the deceleration is proportional to (entry velocity)^2, as is the total heat input to the body. The reasons for the latter proportionality are discussed after (15). Referring back to Fig. 2 it is seen that burnout and hence entry velocities go up with range. Thus the longer the range of the vehicle the more severe are the re-entry problems; a nosecone designed for a range of 1,000 miles cannot be attached to an ICBM and expected to survive re-entry.

Investigation of the maximum deceleration reached reveals some surprising facts. It is given by

$$-\left(\frac{\frac{dV}{dt}}{g}\right)_{max} = \frac{\beta V_E^2 \sin\theta_E}{2ge} = 0.26 \times 10^{-6} V_E^2 \sin\theta_E \qquad (11)$$

Equation (11) shows that the maximum deceleration is independent of all the physical and dimensional characteristics of the body. This deceleration is reached at a height of $\left(22{,}000 \log \frac{22{,}000\, C_D \varrho_0 A}{m \sin\theta_E}\right)$ feet, and the velocity at this time is 61 per cent of the re-entry velocity. Clearly negative heights have no significance here. These facts enable non-dimensional velocity and acceleration charts to be produced in Ref. 4 and they are shown here as Fig. 5. In addition, the ordinate and abscissa show the dimensional values pertaining to our vehicle (i.e., V_E of 22,000ft/sec and θ_E of 23 deg). The maximum deceleration is 49g. Assuming a drag coefficient of 2.0 and a frontal area of 12.5ft^2 gives the height of maximum deceleration as 103,000ft. In practice, calculations would be complicated by the fact that the body would be oscillating slightly.

Before discussing heating during re-entry it is worthwhile to introduce a few ideas about aerodynamic heating in general. It is well known that the air molecules just outside the boundary layer are moving at speeds of the same order of magnitude as the free-stream velocity, while those in contact with the body are at rest. (This neglects "slip" flow, which can occur in very rarefied atmospheres at high speeds.) As usual in this type of problem the velocities are measured relative to the re-entry body. At hypersonic speeds the viscous or shearing stresses in the boundary layer must be very large to produce such a velocity-gradient across this thin layer. This results in a considerable portion of the kinetic energy of the air being transformed into thermal energy, which heats up the boundary layer. The air temperature at a stagnation point is, in the absence of heat transfer

$$T_W = T\left[1 + r\frac{(\gamma-1)}{2} M^2\right] \qquad (12)$$

where T is the absolute free-stream ambient temperature, T_W is the absolute wall temperature (so called because it is the temperature the wall will reach when equilibrium—no heat-transfer between boundary layer and structure—is attained), M is the Mach number, γ the ratio of specific heats (roughly 1.4) and r the recovery factor (which can be explained as follows). A certain percentage of the heat is conducted into the free stream, and thus not all of it is available to heat the boundary layer. Hence the temperature in the boundary layer does not reach the full stagnation value. The factor r is usually somewhere between 0.75 and 0.90, depending on the boundary-layer characteristics. Equation (12) is plotted in Fig. 6.

Heat transferred per unit area per unit time to the re-entry body is given by

$$\frac{dQ}{dt} = \frac{h}{J}(T_W - T_S) \qquad (13)$$

where Q is the heat transferred per unit area (ft-lb/ft^2), J is the mechanical equivalent of heat (ft-lb/BTU), h is the heat-transfer coefficient (ft-lb/ft^2 sec ° R), and T_S is the skin temperature (° R). When $T_W = T_S$ we have no heat transfer and thus T_W is also known as the equilibrium temperature.

From (12) and (13) it is possible to compute the heat transfer, once Mach number, ambient temperature and heat-transfer coefficient are known. However the computation of h, which is a function of position on the body, is a problem of staggering complexity and only the barest elements will be mentioned. It should also be noted at this stage that (12) is not correct if radiant heat

transfer is taking place. The heat radiated by a body per unit area per unit time is

$$\frac{dQ}{dt} = \sigma E (T_S^4 - T^4) \qquad (14)$$

where σ is the Stephan-Boltzman constant and E the emissivity. The effect of radiant heat transfer is to prevent the full adiabatic wall temperature from being reached.

It will be shown later that the skin temperature, and hence radiant heat transfer, depend on the type of material used for the skin; hence, to keep the analysis general, we shall neglect the relief due to radiation. The body re-enters at a Mach number of the order of 20, but its trajectory prevents equilibrium temperatures from being reached until it is going very much slower—if in fact they are ever reached.

The entire heating/time history at each point depends on the heat-transfer coefficient, and attention should be focussed on this quantity. A major fact, from our point of view, is based on an analogy between skin friction and heat transfer. The basis for this analogy is that the mechanism due to viscosity in the boundary layer that produces the skin-friction drag is the same that is responsible for the heat transfer at high speeds. The proportionality between skin friction and heat transfer has been found to hold in a surprisingly wide range of airflows. In fact Ref. 4 shows that for practical re-entry bodies, the total heat transferred by the time of impact is approximately given by

$$\int Q\,dS = \tfrac{1}{4}\left(\frac{C_f S}{C_D A}\right) m\, V_E^2 \text{ ft-lb} = \frac{1}{4J}\left(\frac{C_f S}{C_D A}\right) m\, V_E^2 \text{ BTUs} \qquad (15)$$

where C is the effective skin-friction coefficient (i.e., C_f=skin friction drag/$\frac{1}{2}\varrho SV^2$) and $\int Q\,dS$ is the heat input integrated over the entire body surface.

Equation (15) shows what at first sight seems a remarkable aspect of aerodynamic heating during re-entry. The total heat transferred to the body during re-entry is decreased if the overall drag is increased and, at the same time, the skin-friction drag is prevented from rising as fast. The reason for this can be understood if we consider what happens to the kinetic energy $\frac{1}{2}mV_E^2$ that the vehicle possesses at re-entry. The velocity at impact is computed in Ref. 4, to be

$$V_o^2 = V_E^2\, e^{-\frac{22{,}000\, C_D\, \varrho_O A}{m \sin \theta_E}} \qquad (16)$$

Clearly the exponential term is small, and thus V_O is small relative to V_E. This means that most of the kinetic energy at re-entry has been dissipated as heat in both the body and the atmosphere. From (15) it is seen that the fraction absorbed by the body is $\frac{1}{4}\left(\frac{C_f S}{C_D A}\right)$. The worst heating condition that could possibly occur is when $C_f S = C_D A$, or all the drag is due to skin friction. Then half the heat enters the body and the remainder warms up the atmosphere. The light now begins to shine on the solution of the re-entry problem. In supersonic flow blunt-nosed bodies are well known for their large wave drag and small skin friction, and thus are ideally suited for minimizing the heating problem.

Another important point to remember is that skin friction is markedly higher for a turbulent boundary layer than a laminar one at a given Reynolds number. Therefore every effort should be made to keep the boundary layer laminar as long as possible, by such means as highly polished surfaces. In addition, for optimum design it is important to know where transition to a turbulent layer takes place so that provision can be made to deal with the extra heating. In spite of all that is done to reduce heat transfer the skin still reaches a temperature at which normal aircraft materials are quite useless. Assuming a skin-friction coefficient of 0.03 and surface area of 100ft², $\int Q\,dS$ from (15)=4.6×10^8 ft-lb=5.9×10^5 BTUs, which for our example is 6 per cent of the kinetic energy at re-entry.

So far we have reviewed the overall problem of the total heat input, but it has been pointed out that the heat-transfer rate is a function of position on the body. We now return to the work of Allen and Eggers to find the "hot spots" and maximum heat-transfer rates. That the nose will be the local area subjected to the greatest heat transfer can be seen from the following intuitive argument. No matter how sharp we make the nose it always has a radius of curvature, and there is a stagnation point at which the air is brought to rest and its kinetic energy is transformed into potential and thermal energies. At hypersonic speeds there will be a detached shock-wave in front of, and curving round, the nose. The temperature-rise across a shock depends on the velocity normal to the shock; hence it is greatest at the stagnation point where the flow is normal. The temperature-rise across a normal shock is shown in Fig. 6 for the range of Mach numbers of interest. Hence the peak air temperature surrounding the nosecone of an ICBM will be of the order 25,000 deg F. Dissociation of the air will reduce this slightly, but the order of magnitude remains correct. This temperature decreases as we proceed along the body.

Clearly, sharp-nosed bodies are to be avoided, for they have to

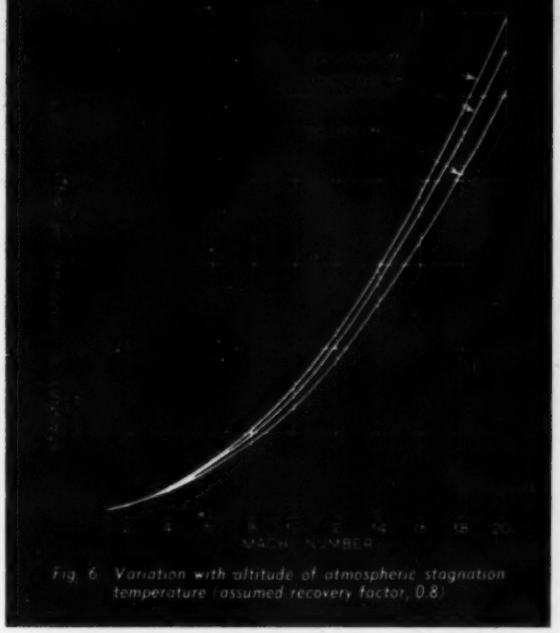
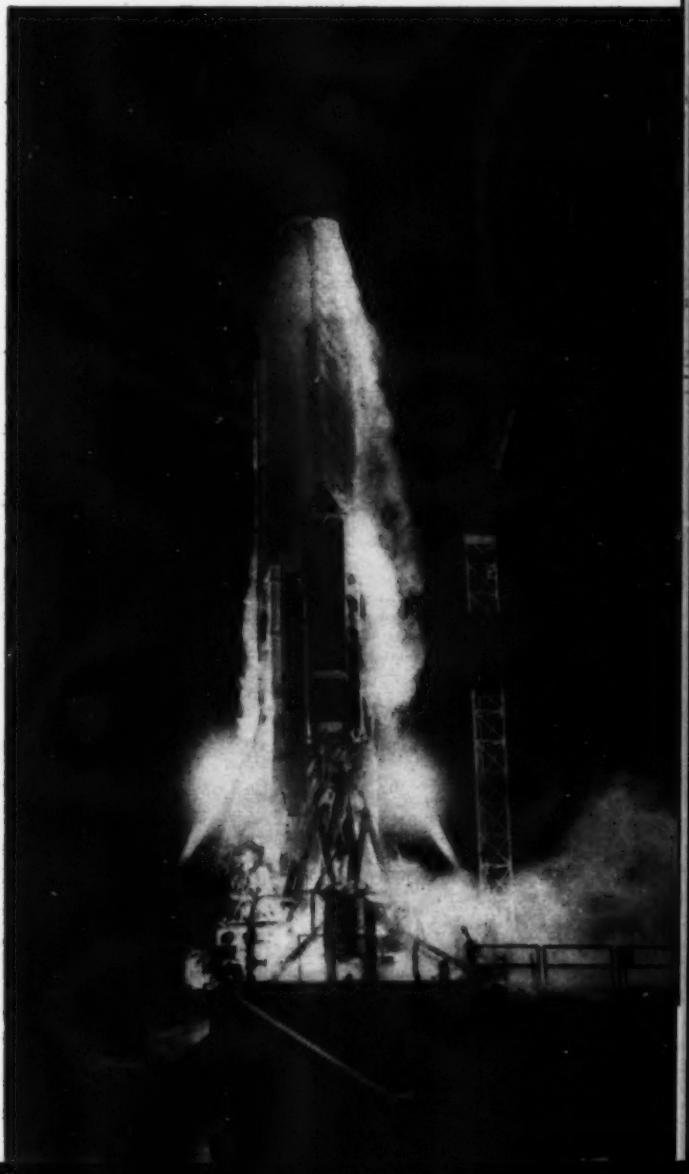
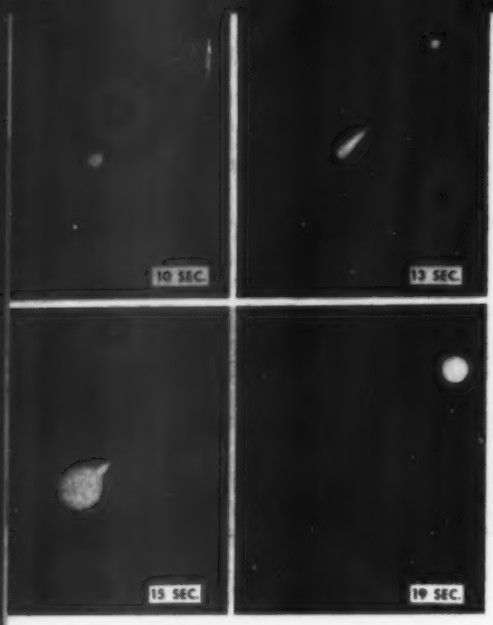


Fig. 6. Variation with altitude of atmospheric stagnation temperature (assumed recovery factor, 0.8)

The nearest approach on a large scale to "parallel" staging is the Atlas ICBM. The dramatic photograph below shows the launch of a unique Atlas—10-B, which was placed in orbit last December 18





The four photographs on the left were taken during the night of May 18 in the neighbourhood of Antigua. They depict the re-entry of the business-end of a Jupiter IRBM fired some 15 minutes earlier from Cape Canaveral. The first photograph (10 sec after first sighting) shows the large rocket body and small instrument package. The latter has disintegrated at 15 sec, while the small nosecone (first seen at 13 sec) flies on ahead. The cone itself is shown below

BASIC BALLISTICS . . .

absorb the heat (in a small material volume) and have the highest heat-transfer rates. Hence they melt much sooner than the relatively blunt body. Heat-transfer rate per unit area at the stagnation point of a re-entry body is, given under somewhat idealized conditions

$$\frac{dQ}{dt} = \frac{8.8}{10^9} V^3 \sqrt{\frac{\varrho}{B}} \quad BTU/ft^2\,sec \qquad (17)$$

where B is the nose radius (ft). This shows that the heat-transfer rate is proportional to the reciprocal of the square root of the nose radius. The maximum heat-transfer rate is given by

$$\left(\frac{dQ}{dt}\right)_{max} = \frac{8.80}{10^9} V^3 \sqrt{\frac{m \sin \theta_E \beta}{3e\, C_D\, BA}} \qquad (18)$$

and occurs at a height of 22,000 $log_e \left(\frac{66{,}000\, C_D\, \varrho_0\, A}{m \sin \theta_E}\right)$. For our missile this means that the peak heating rate is 380 BTU/ft²/sec for a nose radius of 1ft and 760 BTU/ft²/sec for a nose radius of 3in, and occurs at a height of 95,000ft. Now that we have seen the orders of magnitude of the heating problem it is time to see how re-entry bodies can be made to survive this environment.

There are basically two approaches to the solution of this problem. One involves the use of a "heat sink" in which the transferred heat is stored in the body in such a manner that it continues to function satisfactorily. In the second the mechanism of ablation is brought into the picture. The basic principle here is that the material on the surface is allowed to melt or sublime, and as each little element does this it is swept away revealing more material ready to be ablated. The latent heat of melting—that heat which is absorbed by the material as it changes from solid to liquid at the melting temperature—is large for the materials selected for this task. Also it does not manifest itself by a rise in temperature such as occurs when heat is absorbed without a change of state. Thus any element of material absorbs much more heat if it ablates than if it is kept at a temperature just below that of melting. The outer surface temperature of an ablating material will normally be higher than that of a heat sink, and thus its conductivity should be as low as possible to hinder transfer to the interior of the re-entry body.

Some materials used for ablating re-entry bodies do not melt, especially if they are of a fibrous nature. They just sublime, and absorb latent heat as they do so. There is no objection to using both techniques on a single re-entry body. The vital parts in one area may be protected by an ablating skin while in another area the heat can be fed into a sink.

As might be expected, the material properties required for use as heat sinks are entirely different from those needed for ablation. The total heat absorbed by a heat sink, per unit area, is

$$Q = \int_{T}^{T_{max}} \varrho_m L\, C_p\, dT \qquad (19)$$

where C_p is the specific heat, ϱ_m the density of the material and L its thickness. In addition to C_p and ϱ_m, thermal conductivity is obviously important since the heat must be rapidly conducted away from the surface. Table I taken from Ref. 5 shows typical values of possible contenders for the job of heat sinks. It indicates that beryllium is the most useful material—and that, in spite of its great weight, copper is the second choice, and was frequently used before beryllium was made available. Now that manufacturing and other difficulties have been overcome it will most likely be used on many heat sink re-entry bodies in the future.

TABLE I: PROPERTIES OF POSSIBLE HEAT-SINK MATERIALS

Material	Melting Point (deg R)	Weight Density	Specific Heat (BTU/lb deg R)	Thermal Conductivity (BTU/ft sec-deg R)
Aluminium	1,680	169	0.215	0.0366
Beryllium	2,800	114	0.52	0.0255
Copper	2,440	559	0.092	0.0632
Iron	3,260	492	0.11	0.0121
Tungsten	6,630	1,206	0.032	0.0323

One tacit assumption in the design of heat sink bodies is that the material of the sink will be able to conduct the heat away from the outer edge fast enough to prevent local melting. If this is not possible we are forced to the ablating type of body, which is considered by a number of people in the field to be superior for other reasons. Tests by the General Electric Company discussed in Ref. 5 show that special glass-reinforced plastics can absorb up to 6,000 BTU for each pound of material ablated. In addition, its very low thermal conductivity prevents the heat at the outer surface from reaching the primary components.

Since the process of ablation involves the heating, melting, vaporizing and combustion of the material, and the interaction of these phenomena with the boundary layer—all of which are rapidly varying with time—the theory is singularly difficult, and not yet fully developed outside classified literature. Nevertheless ablating nosecones have successfully re-entered after travelling the "intercontinental" range of 5,500 nautical miles. This is not the first time that a solution to an aeronautical problem has been found before the theory has been completely derived.

The larger the tolerable heat input to the re-entry body the sharper can the nose become, and hence the drag coefficient increases. This means that the maximum deceleration remains constant but the altitude at which it occurs is decreased. This is desirable for two reasons. Firstly the deviations from planned trajectory due to atmospheric disturbances are decreased; secondly, interception is made more difficult.

Conclusions. Reviews of any art or science invariably rely heavily on published literature. The discussion of ballistic trajectories owes a great deal to the Lockheed report by Pollak and Landauer. The sections on multi-stage vehicles are derived from the book *Guided Missile Engineering* edited by Puckett and Ramo. The re-entry discussion leans very heavily on the pioneering work by Allen and Eggers. Finally it is important to point out that the opinions expressed in this paper are those of one member of a large technical staff, and should not be construed in any way as being the opinions of Lockheed's Missiles and Space Division.

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(3) *Guided Missile Engineering*, edited by Allen Puckett and Simon Ramo. Published by McGraw-Hill, 1959.

(4) *A Study of the Motion and Aerodynamic Heating of Missiles Entering the Earth's Atmosphere at High Supersonic Speeds*, by H. Julian Allen and A. J. Eggers: N.A.C.A.T.N. 4047, October 1957.

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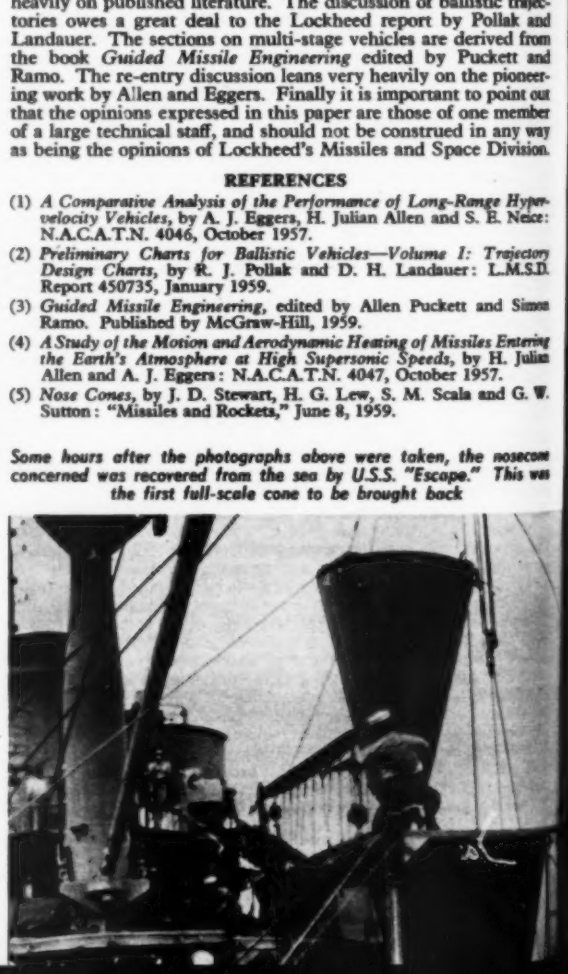
Some hours after the photographs above were taken, the nosecone concerned was recovered from the sea by U.S.S. "Escape." This was the first full-scale cone to be brought back



MISSILES 1959

TEXT BY THE TECHNICAL EDITOR
DRAWINGS BY ARTHUR BOWDEER

IT is customary at this time of the year for *Flight* to produce a review of the world's guided missiles. The task is annually becoming more difficult; not only are there always—alas!—more missiles than before, but many facts previously hidden by security are open for comment. In order to devote proper attention to the really important weapons, older missiles have been dealt with relatively briefly. For more extensive accounts of the latter the reader is referred to our previous reviews, which were published on December 7, 1956, December 6, 1957, and December 5, 1958.

Strategic ballistic missiles (which occupy the first and largest section of this review, starting overleaf) are now in operational service with the U.S. Air Force, the Royal Air Force and in the Soviet Union. To a layman, current hardware is immensely impressive, and nobody who has watched a hundred-ton ICBM take off will readily forget the spectacle. Yet one can appreciate that such things are unnecessarily complex and unwieldy, and that smaller, cheaper and less temperamental ballistic missiles are just around the corner. Before leaving this section it may be said that, but for today's ICBM, tomorrow's military and scientific spacecraft would not even be paper projects.

The next section, dealing with cruise-type missiles, may portray a dying race; but the varied assortment grouped under the heading "battlefield" are very much alive, and are responsible for some singularly keen commercial rivalry. Air-to-surface missiles again embrace many shapes, sizes and missions, and it is in this section particularly that the reader will note our decision to provide three-view drawings of the more important aircraft-shaped weapons. The ASW devices are only marginally our concern; but the surface-to-air family, which follows, again underlines the diversity of configuration which may be evolved to handle a given task. Many systems in this category are being improved electronically, typically by the incorporation of coherent-pulse Doppler radars which can detect targets flying at low-level. In addition, improved radar is frequently being introduced to match increasing missile range. The final category deals with air-to-air weapons, where the most notable trend is the decision by the U.S. Navy to develop a missile with great speed and range which can be carried by aircraft of relatively low performance.

All the missiles in each category are drawn to a common scale, but, for obvious reasons, the same scale has not been adhered to throughout the review.

Launch of Polaris test vehicle

ATLAS

U.S. Air Force (Strategic Air Command); the missile is Strategic Missile 65A, and it forms part of Weapon System 107-A-1.

Intercontinental ballistic missile for deployment from fixed soft installations.

OUTSIDE the Soviet Union, the U.S.A.F. Weapon System 107-A-1, of which the Atlas missile forms a part, is the only ICBM system to have reached the operational stage. It is the outcome of a protracted history, which began with a research and development contract for a 5,000-nautical-mile ballistic missile assigned to the Convair Division of General Dynamics Corporation in 1946. At that time the state of the art was such that the project was little removed from the realms of fantasy, and it was shelved completely between 1947 and January 1951. In 1953, however, there came the thermonuclear break-through, which drastically reduced the size of the warhead and increased the permissible miss-distance; the concept of an ICBM thereafter made sense, and the Atlas programme was placed on a "crash" basis the following year. Pilot production started at Convair's San Diego plant in 1955, and bulk production began in 1957 in the *ad hoc* $40m facility of the company's Astronautics Division. Initial operational capability was achieved two months ago.

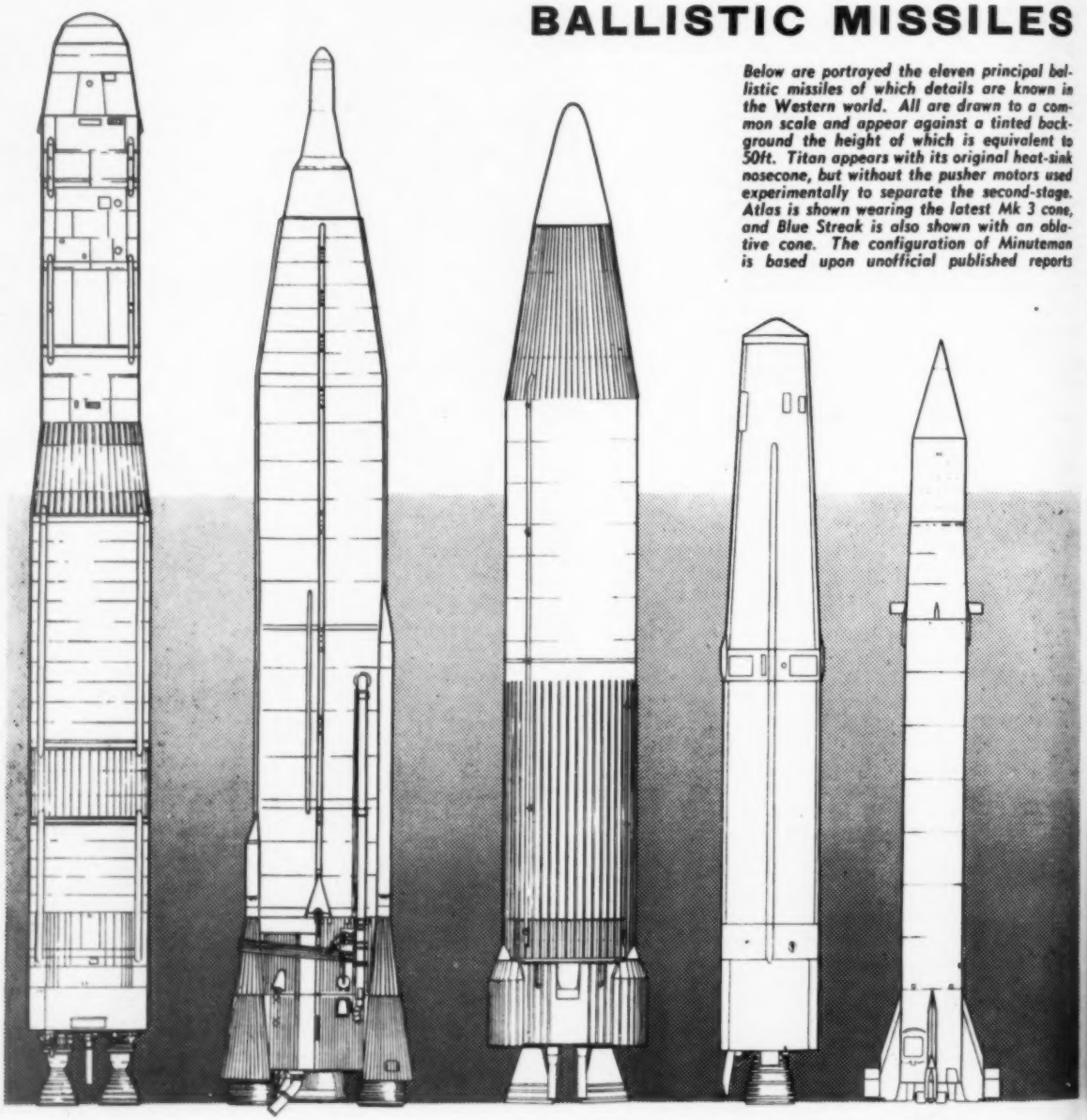
Owing to its early inception the Atlas missile incorporates a number of unique features. The propulsion system consists of a sustainer engine flanked by two boosters, together with a pair of verniers; all five are fired on the ground and the booster assembly is jettisoned during flight. Virtually the entire airframe above the propulsion bay consists of a monocoque propellant tank 10ft in diameter and 60ft long, fabricated from stainless steel as thin as card and stabilized by internal pressurization. Other unusual design choices will become apparent in the ensuing text.

In the fabrication of the tank Convair have evolved unique methods for handling and welding wafer-thin stainless steel. Supplied by the Washington Steel Corp. in rolls some 36in wide, the material used is AISI grade 301, a special cold-rolled austenitic steel. Skin-gauge varies through the 27 sections which form the airframe, but nowhere is it greater than 0.04in. Construction begins by joining a 32ft length end-to-end to form a loop, the butt weld being an edge to edge joint reinforced with an underlying strip. This forms one complete tank section, and the remainder of the airframe is built up by lap-welding (edge over edge) additional sections.

At its forward end the tank tapers to a domed stainless-steel bulkhead. A larger bulkhead is inserted to separate the two propellants, and the tank is completed by the installation of the third bulkhead, of conical form, immediately above the propulsion bay. The final bulkhead is joined by a fixture involving welding arms both inside and outside the tank. The process takes 16 hr, during which time a welder and intercom. operator must remain inside the tank, eight crews each doing a 2 hr shift. Supporting rings maintain the shape of

BALLISTIC MISSILES

Below are portrayed the eleven principal ballistic missiles of which details are known in the Western world. All are drawn to a common scale and appear against a tinted background the height of which is equivalent to 50ft. Titan appears with its original heat-sink nosecone, but without the pusher motors used experimentally to separate the second-stage. Atlas is shown wearing the latest Mk 3 cone, and Blue Streak is also shown with an ablative cone. The configuration of Minuteman is based upon unofficial published reports



Titan *Atlas* *Blue Streak* *Thor* *Redstone*

the tank up to this point, but after the third bulkhead is sealed the internal rings are removed and the airframe remains permanently pressurized at up to 10 lb/sq in by helium; but it can be depressurized and re-entered if the missile is stretched axially.

Prime contractor for the propulsion system is the Rocketdyne Division of North American Aviation. All five motors operate on liquid oxygen and RP-1 fuel fed from the main tankage, each of the three main chambers having its own turbopump. Various types of booster and sustainer engine have been used in the four models of Atlas, but the standard MA-2 system uses an LR89-NA-3 sustainer and LR105-NA- boosters. All three of the main chambers are gimbal-mounted and hydraulically actuated to provide trajectory control. The verniers are likewise gimballed to the sides of the propellant tank, and each is protected against aerodynamic heating by a fairing of phenolic resin. After booster burnout the complete boost package, including the turbopumps and airframe skirt, is jettisoned. After shutdown of the sustainer the verniers may be used to trim the velocity to the exact level needed. Then small retro-rockets are fired to pull the airframe back from the nosecone, which continues to describe a ballistic trajectory for the remainder of its flight.

Two types of nosecone have been produced for Atlas, the contractor for both being G.E.'s Missile and Space Vehicle Department. The original is of the blunt (105 deg included angle) G.E. Mk 2 type, a heat sink being provided by a slab of copper produced as a closed-die forging 63.6in in diameter and weighing 1,115 lb. Although this cone provides satisfactory protection it is giving way to more pointed assemblies of the ablation type which, with their higher re-entry speed, increase the problems of interception and substantially reduce warning time (and also increase payload). The majority of rounds recently fired have worn a GVX-2 cone, these being test prototypes for the final ablation model.

Until recently the guidance system has been of a radio/inertial variety. Its powerful ground-radar is produced by General Electric's military electronics division and the airborne computer is by Burroughs (the system was described in more detail on p. 874 of our issue of December 5 last). Although this system is necessarily retained in the missiles currently classed as operational, the bulk of Atlas production—starting with the E series—will have the 350 lb pure-inertial system originally produced for Titan by American Bosch Arma, who are tailoring it to Atlas against a $53.35m contract placed in September. Sled testing of the airborne portions re-engineered for Atlas is in hand at China Lake. The airborne guidance and instrumentation systems are packaged on the outside of the propellant tank beneath long fairings on opposite sides of the missile. Electrical power is provided by automatic and manually-activated silver-zinc batteries.

Completing the weapon system is the ground support equipment and launch complex. Transportation trailers are made by Goodyear at Litchfield Park, each being welded from steel tubes and incorporating an articulated trailer to carry the boost assembly. On arrival at the operational site the transportation trailer is backed into the missile storage area. The three-engined thrust section of the missile is then attached to the launcher—also by Goodyear—while a pair of caliper jaws at the end of the 70ft erector boom are closed around the nosecone. Thus supported, and internally pressurized throughout, the missile is lifted clear and the trailer driven away. Each round then remains in a horizontal position in a weatherproof shelter until an alert is sounded.

When the latter occurs the erection system, developed by Westinghouse, is energized by a single button. Driven by a 75 h.p. electric/hydraulic system, the roof slides back on rollers while the launcher and erector boom start to pull the missile upright. Erection takes about 115 sec (the time will be further reduced in later emplacements in which the roof slides sideways and not lengthwise), and the check-out sequence is initiated as soon as the cycle begins. When the missile is upright the propellant systems are purged by nitrogen, the propellants are pumped in automatically and the countdown begins.

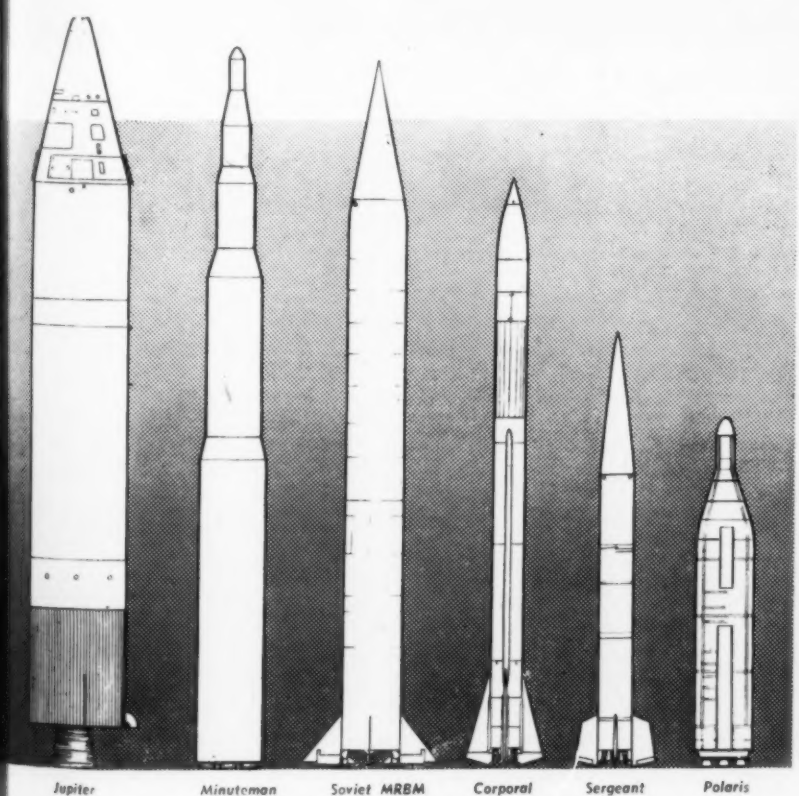
Flight development of Atlas has been conducted with four main series of missile. The first was the Atlas A, fitted with booster engines only and having a dummy nosecone. With a maximum range of some 600 miles, eight Atlas As were fired successfully from June 11, 1957, although a number of rounds had to be destroyed in flight. Next came the Atlas B incorporating the sustainer engine and a separable nosecone. A random failure in the control system caused missile 1-B to break up in the air on July 19, 1958. Fired on August 2, 2-B attained a range of more than 2,500 miles; increased ranges were achieved on August 28 and September 15, and the first full-range flight of 6,325 miles was made on November 28. As noted later, 10-B was fired into orbit (under Project Score) on December 18.

On December 23, the first series C Atlas was launched successfully, differing from its predecessors in such airframe refinements as chemically milled skirt sections to improve the mass-ratio. Both 1-C and 2-C (fired on January 27) telemetered data on the performance of the Bosch Arma inertial elements, although these were not coupled to the engines. Most Cs were programmed to fly 4,000 to 4,500 miles. The D-type Atlas entered the flight-test stage on April 14. In addition to minor refinements throughout the airframe, Atlas D incorporates a skirt largely of glass-fibre and redesigned instrumentation and guidance fairings, that on one side being much shorter than previously. A new launcher hold-down system is employed, the attachment arms entering the missile through large fairing doors which close after lift-off.

Last April 14 ushered in both the flight-test programme of the Atlas D and also a disastrous series of unsuccessful missions. The first of the new missiles (3-D, fired on that date) could not free itself from one of the hold-down arms—which are designed to let go when thrust exceeds weight by 8,000 lb—without dislocation of the glass-fibre skirt, and rupture of a pressure line. It finally left on an initial flight path far from the vertical, and was destroyed at an early stage by the range safety officer. Next to go were 5-C and 5-D, both of which aborted owing to incorrect fuel flow. These were followed by 7-C and 7-D (both fitted with the RVX-2 nosecone), which respectively failed as a result of a ground-guidance malfunction and a "human error." From mid-June to mid-July Convair Astronautics and their sub-contractors worked feverishly to try to achieve initial operational capability not more than a few weeks later than the scheduled date of August 1.

After extensive ground testing it was determined that incorrect propellant mixtures were rupturing a tank bulkhead, and the problem was finally cured by effecting three minor changes to a fuel-disconnect valve. To prove the new valve 8-C (again wearing the ablative cone) flew 6,300 miles late in July, followed by 11-D (wearing the Mk 2 heat-sink cone) at the end of the month. By August 27, four consecutive successes had been recorded, and initial operational capability was achieved by Strategic Air Command on August 31. On that date the 567th Sqn. of SAC's 1st Ballistic Missile Division launched their first round (12-D) from Vandenberg A.F.B., and achieved impact within one mile of their target 4,480 miles westward, near Wake Island. This was the first ICBM fired on the West Coast. At that time 26 Atlases had been launched, of which 11 had achieved 90 per cent of their test objectives, seven from 25 to 90 per cent and eight less than 25 per cent.

Today the Astronautics Plant is nearing peak output, against contracts which must amount to 250 rounds, each costing some $2m. Ground testing is continuing at Sycamore Canyon and Edwards, and flight testing is still in full swing from Cape Canaveral. The definitive nosecone (*Flight*, October 16) was flown on Atlas 18-D on October 6, achieving full design range. Deliveries are being made to the 1st B.M.D., the headquarters of which at Vandenberg now has its three-launcher complex. Work is well advanced on full complexes at the following air force bases: Francis E.

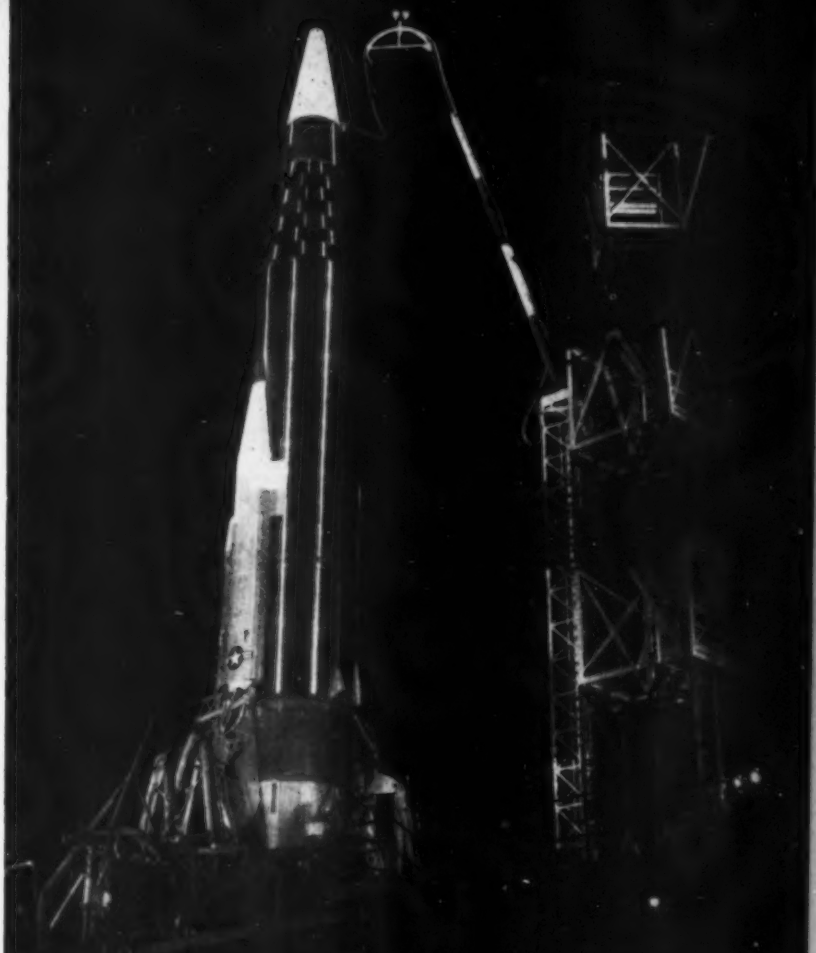


MISSILES 1959...

Warren (Cheyenne, Wyo.); Offutt (Omaha, Neb.); Fairchild (Spokane, Wash.); Forbes (Topeka, Kan.); Schilling (Salina, Kan.); and Lincoln (Lincoln, Neb.). Each squadron will have ten missiles, those in Kansas and Nebraska being assigned to the 2nd Air Force and the remainder to the 15th Air Force. Training facilities are based at Sheppard and Chanute A.F.B.s As an indication of the civil-engineering work required at each base, the contract for the three triple complexes at Francis E. Warren is for $12,422,104; that for two triple complexes at Forbes amounts to $6,938,450. The current Fiscal Year includes $85m as an initial payment on eight squadrons additional to those mentioned above.

In conclusion something should be said of the importance of Atlas as a booster for spacecraft. Atlas 10-B was fired under Project Score on December 18 last, the complete airframe remaining in orbit until January 21. For the future, Atlas will boost the first Project Mercury manned capsule into orbit, the first instrumented space probe (Atlas-Able 4), the first heavy satellite into Polar orbit (the definitive Discoverer), the first medium-energy vehicle into high orbit (Vega) and the first high-energy vehicle into distant orbit (Centaur).

SM-65A Atlas (D model): height, 86ft 6in; booster skirt width, 16ft; body diameter, 10ft; launch weight, 253,000 to 261,000 lb; launch thrust, 390,000 lb; design range, 5,500 nautical miles (6,333 miles); apogee, over 600 miles; burnout and re-entry speed, about 16,000 m.p.h.



Atlas 7-C is here depicted on its pad at Cape Canaveral shortly before launching

BLUE STREAK

Royal Air Force (Bomber Command).

Long-range ballistic missile for deployment in fixed, hard emplacements.

EXISTENCE of a British strategic ballistic missile was announced by the Minister of Defence in August 1957. In his statement he described Blue Streak as being "a rocket of more advanced type" (apparently in comparison with Thor), and it has always been officially described as a long-range ballistic missile, or LRBM. Although initially owing much to American work in such fields as the airframe, inertial guidance, propulsion, development techniques and ground-support equipment, the British weapon system is deliberately being conducted in an insular manner and is not being compromised in any way by relying upon the accomplishments of any other nation. The key to the thinking behind the programme is that Britain needs a strategic missile which she can truly call her own, and which can be deployed in any part of the Commonwealth.

Prime contractor for the weapon system is de Havilland Propellers Ltd. Manufacturers of the airframe and its associated test equipment is de Havilland Aircraft. Propulsion has been entrusted to Rolls-Royce Ltd., who have for four years held a licence to develop and manufacture large liquid-propellant engines incorporating design information from the Rocketdyne Division of North American Aviation. Chief contractor for guidance is the Sperry Gyroscope Company. The work is now dispersed throughout a large section of the British missile industry. The prime contractor's effort is concentrated at Hatfield and at a London office; rig testing is being done at Hatfield, static firings of the engines is in hand at the R.P.E., Westcott, and at the Ministry of Supply establishment at Spadeadam Waste in Cumberland, and captive firings of a complete missile will shortly begin at the last-named location.

Blue Streak's twin engines appear to confer more thrust than would be needed by a vehicle intended to propel a modern thermonuclear warhead a distance not greater than 3,000 miles. It may well be that excess thrust is incorporated to provide for future "stretch"; and this would also enhance the value of the vehicle as a booster for spacecraft. The engines are gimbal-mounted side-by-side to the base of the main propellant tank, and each is flanked by the exhaust stack from its associated turbopump gas-generator. Discounting these stacks, there is no evidence of any vernier motor; and no retrorocket can be seen either. Construction of the main tank sections appears to be of a unique character, the thin stainless-steel monocoque being stabilized by internal pressurization of the liquid-oxygen tank and external longitudinal corrugation of the kerosine tank. Total propellant capacity appears to be some 20,000 Imp. gal.

From the outset Blue Streak has been designed for installation in hard sites. The user service has not been named, but it would be logical to suppose that it will be R.A.F. Bomber Command. American journals have suggested numerous locations within the Commonwealth where Blue Streak underground silos could be installed. Nothing has been divulged regarding the ground-support equipment, nor whether the fuel will be RP-1 or a standard jet fuel. Air-lifting of the missile will eventually be handled by Transport Command Britannics, pending delivery of which the only aircraft available will be the C-130A Hercules of the R.A.A.F.

The latter will almost certainly be required to transport the development Blue Streaks to Woomera when the flight-test programme begins in perhaps a year's time. The test launch emplacements near Lake Hart, some 40 miles north-east of the Woomera range-head, are reported to be in an advanced state of construction. Located at the side of a cliff, the complete installation also includes a liquid-oxygen production factory. The range itself is being instrumented over 1,400 miles to Port Hedland, and it should be possible to achieve full-range flights beyond this point across the Indian Ocean towards Christmas Island.

As a booster for spacecraft Blue Streak is the only British vehicle likely to be available for about a decade. Although the Prime Minister has said "design studies are being put in hand," no official programme for its use in this role has been made public; but an extensive dissertation by the prime contractor was summarized in our issue of September 4 (page 110). Using a modified Black Knight as the second stage a payload of some 7,000 lb could be placed in a 300-mile circular orbit.

Blue Streak (approximate data): height, 81ft; skirt width, 15ft; body diameter, 10ft; launch weight, 175,000 lb; launch thrust, 300,000 lb; design range, 2,500 nautical miles (2,879 miles); burnout and re-entry speed, about 13,000 m.p.h.

BLUE WATER

British Army.

Tactical ballistic missile for mobile front-line employment; officially termed a "short-range corps-support weapon."

FOR over two years English Electric Aviation have been acting as foster-parent for the Corporal missiles currently used by the British Army. The company has now been selected to manage the development of a system to replace the American weapon during the early 1960s. Very few details of the new system have been divulged; even the code name, given above, has only been reported unofficially.

It would, however, be logical to suppose that the missile will have a payload/range performance at least as good as that of the American weapon and possibly matching that of Sergeant. Solid-propellant propulsion would confer many advantages; and it is virtually certain that in operational use one or more Blue Water missiles will be carried from a self-propelled trans-

porter/erector from which they could be launched within a few minutes of arriving at a suitable location. Lightweight inertial guidance and the ability to carry a variety of nuclear warheads are also logical assumptions.

CORPORAL

U.S. Army and British Army; the missile is M4 (SSM-A-17).

Tactical ballistic missile for mobile deployment.

STEMMING from the Corporal E research vehicle of 1951, this long-established weapon system was the first involving a ballistic missile to be deve'oped in the Western world, and for five years it has been operationally deployed with the U.S. Army, both within the U.S.A. and in other theatres (including Western Germany). For more than two years it has also been in the inventory of the British Army, and two regiments of the Royal Artillery are equipped with it. A full history and description appeared in our 1956 Missiles issue (page 904).

M4 Corporal: height, 46ft; body diameter, 30in; fin span, 84in; launch weight, 11,000 lb; launch thrust, 20,000 lb; design range, 75 miles; burnout speed, M 3.5 (2,300 m.p.h.).

JUPITER

U.S. Air Force (Strategic Air Command); the missile is Strategic Missile 78.

Intermediate-range ballistic missile for mobile deployment.

THE chequered political background to this fine weapon system was outlined in some detail in our 1958 Missiles issue. When the Army Ballistic Missile Agency was established in February 1956 its primary responsibility was the development of an intermediate-range ballistic missile—then an entirely new concept—for mobile deployment by the U.S. Army. The great development team at Huntsville, under Dr. Wernher von Braun, were then the most experienced ballistic-missile designers in the Western world, and the complete Jupiter weapon system rapidly crystallized. But in November 1957 the entire programme was thrown into jeopardy by the famous Memorandum by Charles Wilson, then Secretary of Defense, forbidding the Army to develop any weapon with a range greater than 200 st. miles. Since that time the ABMA and the missile division of Chrysler (prime contractor for production) have co-operated to develop the complete weapon system for operational deployment by the U.S.A.F. Strategic Air Command.

In planning Jupiter, the ABMA engineers regarded the weapon as an extension of artillery and not as a replacement for the manned bomber; and, although a sweeping generalization, this statement explains the mentality which has eschewed large concrete emplacements and instead has produced a simple assemblage of thrust unit and warhead which can be transported by a mobile task force, erected in the field and fired from a simple lightweight launcher (a steel ring standing 6ft off the ground). Owing to the politics already outlined it is doubtful if this weapon system will be as widely deployed as will the more vulnerable Thor. It is, however, already performing sterling service as a booster for spacecraft.

Propulsion is provided by a Rocketdyne S-3D engine, essentially similar to the MB-3 used in Thor, with a single gimbal-mounted chamber rated at 150,000 lb thrust at sea level. The turbopump feeds liquid oxygen and RP-1 at the rate of 4,400 U.S. gal/min for up to 157 sec, and its gas-generator exhaust is dumped overboard through a swivelling nozzle which acts both as the vernier motor and the roll-control jet.

Surrounding the powerplant is a tail section of 2024 aluminium alloy, stabilized by axial corrugations and assembled by flush riveting. The main tankage section is a pure cylinder, fabricated by welding together seven sections of 5086 aluminium alloy initially of 0.055in thickness but machined down to 0.04in over most of its area. Explosive bolts join the top of the tank to what is known as the aft section (of the nose), which is built up from magnesium-thorium sheet and tapers at the same 27 deg angle as the nosecone. The latter, also attached by explosive bolts, is of the ablative type and has a nose radius of some 12in. It is fabricated by Goodyear and was the first full-scale cone ever to fly a full-range mission and be recovered. The ablative surface is built up from glass/phenolic laminates, and it is stabilized by four attitude-control jets together with a small spin-rocket to promote rotation in roll and thus ensure uniform ablation all round.

Jupiters and Redstones on parallel lines in the Chrysler-operated missile plant near Detroit

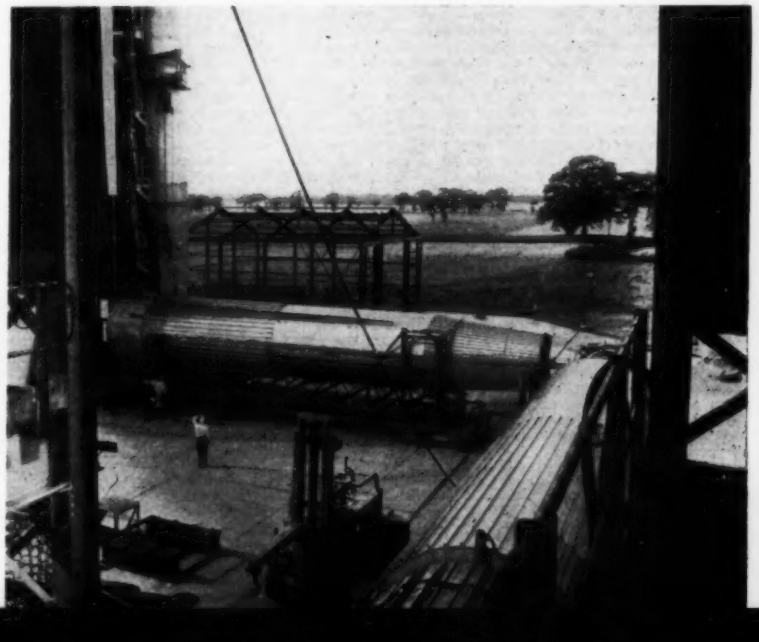
Jupiter's "Delta Minimum" guidance is all-inertial, and it stems from the system developed by ABMA for Redstone. Prime contractor for production is the Ford Instrument Division of Sperry-Rand. The system includes a stabilized platform, with air-bearing gyros, an unusual feature of which is that the gimbal rings are mounted on the outside of a fixed hub, the converse of usual practice. The system includes an airborne computer. Total guidance weight is 450 lb, 150 lb less than that of the Redstone system. It is mounted in the nose aft-section and, after the latter has separated from the thrust unit, continues to control the trajectory of the nose with a small Thiokol solid-propellant vernier motor. When the correct trajectory has been achieved the nosecone and warhead are separated from the guidance package by a further ring of explosive bolts.

In operational deployment with Strategic Air Command, Jupiter Squadrons will be armed with 15 missiles, which during fixed-base operations would be deployed at five triple sites disposed at distances of up to 100 miles from a central receipt, inspection and maintenance facility. Each emplacement will be entirely above ground, and will require the attendance of some 20 vehicles. Following the system developed initially for Redstone, missiles are transported on lengthy trailers and erected by cables passed over an H-frame and A-frame which pull the Jupiter upright on to its mobile launcher. Hydraulic snubbers catch the missile when its c.g. has passed the hinge axis, so that it assumes the vertical position gently. Once the missile is erected, the base shelter, built by Aeronca, is opened up around it. Fabricated from 20 "orange peel" sections, this shelter protects personnel and equipment during the pre-launch cycle. According to an unofficial report the reaction time of a complete squadron depends on its manning status, but that at present six rounds will be kept on launchers in a T-15 min condition, six would be in a state of readiness and three would be unavailable for reasons of unserviceability or routine checking.

Jupiter was the first IRBM to be fired (in March 1957), notwithstanding the fact that two previous rounds malfunctioned. The first Jupiter to fly achieved its full design range. Two subsequent milestones were the recovery of a scale-model nosecone in August 1957 and the recovery of a full-scale cone after a full-range flight on May 18, 1958. On July 17, 1958, the guidance system gave a perfect impact in a designated area. On December 13 last a full-range mission was flown by a cone containing a monkey and extensive instrumentation in addition to a simulated warhead.

Since June 1956, Chrysler have been co-operating closely in the evolution of the complete system, and—notwithstanding the political background—claim to have established a record minimum lead-time of three years. Their authorization to go into production came in August 1957, and letter contracts the following November covered manufacture of the missile and more than 50 of the 225 items of ground-support equipment. The firm's total missile work, including Redstone, comes to $450m. The first Chrysler-made production Jupiter was successfully fired by an Army crew

A pair of Blue Streak airframes are here seen at an outdoor test site at Hatfield



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from Cape Canaveral last January 22. Army teams at Huntsville are training U.S.A.F. personnel to operate the system, and already the 864th, 856th and 866th Strategic Missile Squadrons have been activated (in that order). The eventual location of these units has yet to be announced, but it has been officially stated that from three to five Jupiter squadrons may be deployed in Europe, and that the first of these may go to Italy before the end of this year.

SM-78 Jupiter: height, 60ft; body diameter, 8ft 9in; launch weight, 110,000 lb; launch thrust, 150,000 lb; design range, 1,500 nautical miles (1,727 miles); burnout and re-entry speed, 10,000 m.p.h.

MINUTEMAN

U.S. Air Force (Strategic Air Command); the missile portion of this weapon system is Strategic Missile 80.

Intercontinental ballistic missile.

DURING the past ten years the U.S. Air Force have learnt a tremendous amount about strategic ballistic missile systems. By 1957 it was becoming clear that a specification should be issued for a second-generation missile which would not be merely an improvement of the current Atlas and Titan, but would be the first of a new family of weapons stemming from a new concept of what was really required and how that requirement should be fulfilled.

Merely as a result of adopting a more rational approach the Minuteman system will, in comparison with its predecessors, be appreciably smaller, lighter, simpler, cheaper and more mobile; it will have a very much reduced reaction time, will be less vulnerable and should prove a far more effective deterrent. In a recent appraisal Maj-Gen. Ben. I. Funk described the system as an "economic breakthru considerably less expensive than Atlas or Titan"; and so attractive is Minuteman appearing that the entire programme has been substantially accelerated.

A fundamental factor in planning the system as a whole is that the U.S.A.F. consider that it will not be many months before no reasonable amount of hardening will suffice to offer protection to a launch-emplacement the geographical co-ordinates of which are known. Accordingly, the majority of the Minuteman missiles will be assigned to mobile task forces with no fixed location.

Like other U.S.A.F. ballistic weapon systems, responsibility is managed by the A.R.D.C. Ballistic Missile Division; systems engineering and technical direction is vested in Space Technology Laboratories and the prime contractor (officially designated "assembly and test contractor") is the Aero-Space Division of the Boeing Airplane Company. In turn the last-named are in the process of placing numerous sub-contracts for the entire system.

Unlike any previous "Western" missile, Minuteman will have three stages in tandem. Originally it was anticipated that the missile could be used with either the first or the first and second stages removed, but in practice it appears that it will always be employed as a self-contained three-stage package with intercontinental range. The three stages will always be joined in order to take advantage of the ability of the remainder of the system to remain at "almost instant" readiness.

Each of the three stages will contain a solid-propellant rocket engine. In the development of these three powerplants the entire technology of solid rockets is being strained to the limits; not only does the design performance exceed that of any other solid motor but the first stage will be very much larger even than that of Polaris or Pershing. Early this year contracts for all three stages were placed jointly with Aerojet-General ($85m) and Thiokol ($77m).

First-stage propulsion is being handled by Thiokol, the Aerojet back-up work having been rendered unnecessary by the excellent progress made by Thiokol at Huntsville and Brigham City. Thiokol have cast a number of grains for the first-stage engine, each measuring some 5ft diameter by 25ft in length. The propellant has not been divulged, but unofficial reports state that it will be either polyurethane or polybutadiene acrylic acid. Both materials have apparently demonstrated their ability to achieve a shelf-life of three years, while meeting the required specific impulse. The case for the first stage will be either fabricated by winding many miles of reinforced-plastic tape or by welding or deep-drawing seamless stainless-steel sheet (Solar Aircraft have installed furnaces for heat-treating Minuteman first-stage chambers made by the latter method). At the lower end of the first stage are four parallel/divergent nozzles. Each has a final diameter of some 15in and is equipped with a jetavator thrust-deflection system for trajectory control.

Second-stage propulsion, again with four nozzles, is the responsibility of Aerojet, although Thiokol are working on a back-up proposal employing a different type of case (G.E., one of Thiokol's subcontractors, is using roll-forming). Propulsion of the third stage is again an Aerojet responsibility backed up by Thiokol, although in June a $15,327,000 contract was placed with the Hercules Powder Company for a study of another alternative third-stage motor. The Hercules propellant will be double-based, and it is reported to be contained in a case of glass-reinforced plastic. At the precise third-stage burn-out velocity a number of explosive plugs in the forward end of the case will be detonated. The jets issuing from the holes will cause reverse-thrust, and the warhead will separate.

Guidance will be all-inertial, and almost every portion of the system will be smaller and lighter (aggregate weight has been estimated at 180 lb) than in previous ballistic missiles. Contractor for guidance is the Autonetics Division of North American Aviation. Sled testing of the airborne system has already started and a reliability study is in hand on diodes, many of which will be employed. Firestone are responsible for the flight-control checkout console.

Electric power for the control system will be provided by Cook auto-activated silver-zinc cells, and the a.p.u. employs a solid-fuel gas-generator by Standard Oil of Indiana. The smallest warhead will have a yield of approximately 1 MT. It will be protected by an advanced nosecone, for which a $36,665,000 contract has been placed with Avco's Advanced Research and Development Division. Doubtless the cone will superficially resemble the G.E. Mk 3 used in the operational Atlas.

Although relatively small and simple, the Minuteman will still be a highly sophisticated piece of hardware, and for transportation purposes it has been likened to an egg-shell. Enormous effort is being applied to the problems of manufacturing and deploying the production missiles. Early this year the U.S.A.F. studied several Mid-West ordnance facilities with a view to tooling them for Minuteman assembly and re-cycling of completed missiles, but as things stand the work will be concentrated in Seattle. Regarding deployment, it was thought a year ago that 2,000 production missiles would be housed in 2,000 holes to be dug in almost every state west of the Mississippi. Today it is unofficially averred that between 805 and 2,600 missiles—the smaller number is the more recent estimate—will be delivered, and that more than half of them will be mounted either on railway flat cars, highway vehicles or barges.

Notwithstanding its relative fragility, Boeing hope to transport completed missiles as an assembled unit from plant to pad. Utility Trailers are delivering the 70ft transporter which will accommodate all three stages. The assembled Minuteman can also be carried by any standard U.S.A.F. freight aircraft, and the weight of complete missile and immediate ground-support equipment (presumably transporter) has been given as 90,000 lb.

Squadrons emplaced at fixed sites will have six or seven unmanned remote pads disposed radially about a hard centre located at a depth of perhaps 50ft. As an indication of the size of the silo a glance may be cast at Minuteman holes already in existence at Edwards A.F.B., dug in order to prove the first-stage engine, silo configuration and environment and for research into absorption characteristics, gas dispersal and the design of the flame deflector. There are two holes at Edwards, with their centres 400ft apart. Each has a diameter of 26ft and a depth of 83ft and it provides room for the silo itself (a tube with a diameter of 18ft) together with an elevator for personnel and equipment. In operational service each silo would be an unmanned, silent emplacement, guarding a missile ready to fire literally at a moment's notice. The various silos would be linked to the underground squadron centre by an unjammable communications system (reported to be of a novel type).

As already noted, most Minuteman missiles will be mobile. According to Brig-Gen. A. W. Betts, "It is planned to put some Minuteman missiles in concrete, but a sizeable portion of this force will be mobile to get the enemy off-balance." The exact form taken by a mobile Minuteman task-force has yet to be determined, but it is obvious that it will have to be manned continuously. It may even prove possible to launch the missile from the transporter which carries it from the plant.

Development of the system has been incredibly rapid. Already appreciable portions of hardware are appearing, and early in September a complete tethered first stage was fired from one of the silos at Edwards. At Cape Canaveral, from two to four Minuteman pads are being installed above ground together with one silo and a separate assembly and checkout area. Such firms as Radiation Inc. and United Electrodynamics have received substantial contracts for the advanced digital telemetering system which will be employed and Consolidated Western Steel are manufacturing the servicing towers and umbilical masts. Fiscal Year 1960 provided $53m, to which in July the House added a total of $87m to accelerate research and development. Initial operational capability is planned for late 1962, and a substantial quantity should be at instant readiness the following year.

SM-80 Minuteman: height, about 55ft; max. first-stage diameter, about 5ft; launch weight, less than 90,000 lb; design range, 5,500 nautical miles (6,333 miles); burnout and re-entry speed, over 15,000 m.p.h.

PERSHING

U.S. Army.

Medium-range ballistic missile.

EARLY this year Neil McElroy, U.S. Secretary of Defense, lifted the decree by his predecessor which forbade the U.S. Army to develop any missile with a range greater than 200 miles. At that time the Army Ballistic Missile Agency had already completed a study of a replacement for Redstone, and as the Pershing it has now been put out to industry for final development and production.

Prime contractor is the Orlando, Fla., Division of The Martin Company. The weapon system as a whole will be much simpler, lighter and cheaper than that of its predecessor. Operationally it will be far more flexible and, having solid-propellant propulsion, should have a reaction time of very few minutes. The missile itself resembles a miniature Titan, having two stages which separate at about 40,000ft altitude. Propulsion for both stages is being handled by the Huntsville plant of Thiokol, who have sub-contracted casings to Pratt & Whitney Aircraft, who Floturn them in stainless steel. It was announced in January that the first stage engine had been fired. Inertial guidance is said to be the responsibility of the Eclipse-Pioneer Division of Bendix, and the stable platform may include a descendant of the long-established LEV-3 air-bearing gyro. Beneath an ablative-type nosecone will be housed a nuclear warhead with a yield of up to 1 MT, with a fuzing and arming system by Bulova. Unlike Redstone, Pershing will be carried on a dual-purpose transporter/erector, which will be produced by the accessories division of Thompson Products. This vehicle is intended to have an exceptional cross-country performance. The ground equipment includes a Stratos compressor delivering at 3,000 lb/sq in.

In its first year (FY58) Pershing was voted $20m; in FY59 (which ended last June 30) the system was awarded $100.2m, and the appropriation for FY60 is $131.6m. One of the first letter contracts was signed last month; valued at $24m it provided for prime contractor's engineering services and technical activities. Initial operational capability is timed for early 1961. Pershing will be a direct replacement of Redstone and will be employed as a selective-

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range weapon. According to *Aviation Week* the first user will be the Southern European Task Force of the U.S. Army, with headquarters in Verona, Italy.

Pershing: height, probably about 40ft; launch weight, under 35,000 lb; design range, nominal 100 to 300 miles (but unofficially reported to be 500 to 750 miles); other details classified.

POLARIS

U.S. Navy.

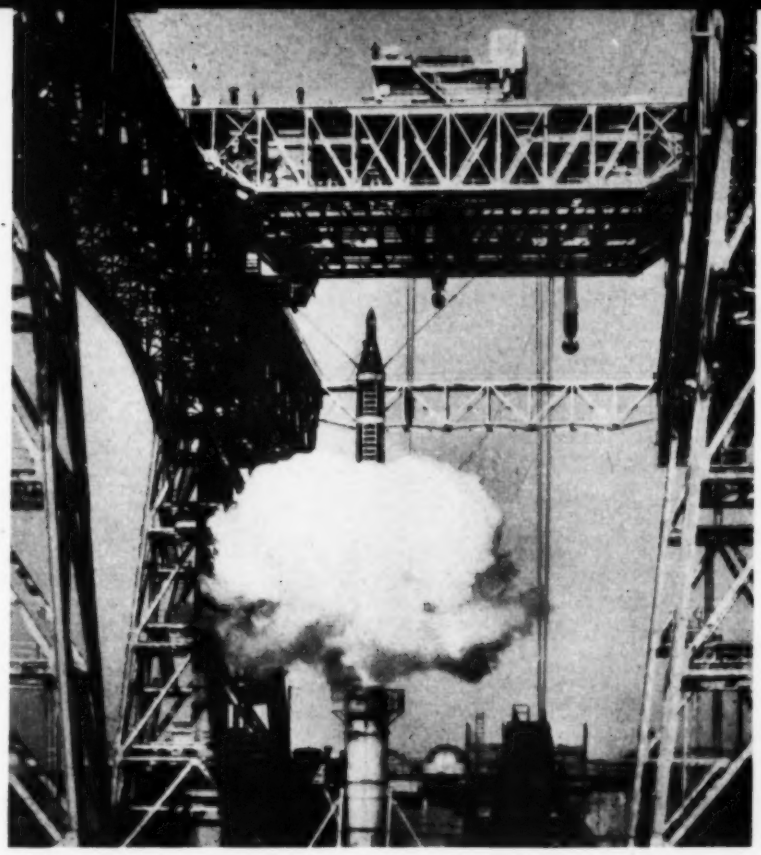
Advanced intermediate-range ballistic missile for launching from submerged or surfaced submarines, surface ships or shore installations.

DESCRIBED by an American Admiral as "mating of the Hawk with the Shark," the Fleet Ballistic Missile System is likely to prove the most effective deterrent yet conceived. The concept of a strategic ballistic missile which could be launched from a submarine is at least five years old; but until 1957 it was regarded as being largely beyond the state of the art, and not even its most ardent proponents believed that it could be made operational before 1967. Such has been the fantastic progress by the prime contractor—the Missiles and Space Division of the Lockheed Aircraft Corp.—that, matched by equivalent progress with the mighty nuclear-powered submarines which will carry the weapon, initial operational capability will be achieved before the end of 1960.

Polaris is a squat package of exceptionally strong stainless-steel sheet, housing two stages of solid propellant and carrying at its upper end a thermonuclear warhead of substantially reduced diameter. The missile is stored inside a vertical tube, where it remains connected to multiple checkout systems, ground-servicing supplies and electric circuits which continuously feed in the precise position of the parent submarine to the moment of launching. It is then ejected from its tube by inert gases, which drive it out like a shell from a gun. Once it has left the launching tube Polaris discards the sabot sections which render it gas-tight during the firing, and then continues to the surface as a result of its own momentum. So great is its momentum that it breaks the surface of the ocean and rises like a porpoise, until at about 80ft altitude the first-stage engine is fired. It thereafter behaves like any other ballistic missile, but the fact that on each mission it is fired under gas-pressure, ejected through the ocean, driven by rocket through the atmosphere and then follows a ballistic trajectory through outer space before re-entering at a hypersonic speed, means that the development problems have been stupendous.

Like any modern solid-propellant missile, the airframe consists essentially of the casings for the propulsive grains. Propulsion contractor for the first stage is Aerojet-General. This portion of the missile has a diameter of 54in and a length of some 12ft, and the single grain of high-impulse propellant which it contains is said to measure 53in diameter × 105in. To reduce length and improve control the gas issues through four nozzles, each of which has a jetavator to provide thrust deflection. The four jetavators are individually controlled to govern the flight of the missile in pitch, yaw and roll, and a tremendous amount of development has gone into their design. In our 1958 review of the system 220,000 lb/sq in was given as the u.t.s. of the steel employed in the casing, but recently Ryan announced that they were working on Polaris chambers in steel with a u.t.s. of 305,000 lb/sq in. In July the U.S. Navy stated that the casing strength and specific impulse necessary for a range of 1,200 n.m. had been successfully attained.

Immediately above the first stage, and having the same diameter (and possibly a similar quartet of nozzles), is the second stage housing a grain 53in in diameter but only 47in in length. Second-stage thrust is less than that of the first stage, since the latter acts as a booster to confer initial acceleration much higher than in any previous ballistic weapon. Aerojet-General and Thiokol are sharing the responsibility of providing propulsion for the second stage, and it may well be that an additional jetavator system is carried by it.



A tethered Polaris test vehicle is here seen being fired from an experimental launching tube

At second-stage burnout, the chamber is vented through four small nozzles disposed at 90 deg around the upper part of the casing in order to pull the complete second stage back from the warhead. Before leaving the propulsion section it is worth noting that the first stage may be programmed to ignite below the surface of the ocean should this be desirable.

In the matter of guidance the Fleet Ballistic Missile System poses exceptional demands. The precise geographical co-ordinates of the parent submarine must be known from the moment it slips its moorings; and for this purpose the NAA Autonetics Division provide the Autonavigator inertial system and Sperry provide the Ship's Inertial Navigation System—Polaris submarines will have either—which maintain an exact record over a period of many days and at the appointed place for firing feed in trajectory data to the missile chosen. When the missile is fired the input of data is stopped and the Polaris thereafter relies upon its own inbuilt Q-Matrix inertial system, reported to weigh only 150 lb, which was evolved by the Instrumentation Laboratory of the Massachusetts Institute of Technology and is now in production by G.E. After second-stage burnout the warhead separates and continues alone. No details are known of its stabilization system, but it is clearly protected behind an ablative-type nosecone of a pattern developed during extensive test firing of X-17s. Warhead yield is said to be about 1 MT.

In the development of the FBMS, Lockheed and their sub-contractors have had to prove the operation of an enormous and widespread weapon system which breaks new ground in many areas. Flight-testing of vehicles resembling the present missile began on September 24, 1958, when the first of the AX series was launched from Cape Canaveral. Previously 21 large devices had been fired over a period of 18 months in the exploration of a number of basic problems.

The AX vehicles were externally almost identical to the operational Polaris, and all were provided with a representative first-stage engine with four nozzles provided with jetavators programmed to tilt the missile out to sea shortly after launching. From December 30 onwards a separating second stage, complete with powerplant, was incorporated. By the end of February 26 AXs had been fired, of which 22 were described as fully successful. At Cape Canaveral Lockheed have a large above-ground emplacement. Missiles are brought in on a transporter/erector with a stubby hinged erecting beam. The latter places the round on a lofty fabricated launcher of cylindrical form, with blast holes for the rocket flame. Additional equipment includes a Corporal-type servicing arm, a railed servicing tower and an umbilical pylon from which connections are made at four points on the tapering guidance portion between the warhead and the second stage.

A more advanced series of vehicles, starting with AX-11, started to fly early in July. The first had to be destroyed after 73 sec. On July 15, during the first flight of the complete guidance system, the loss of a jetavator resulted in a spectacular display of aerobatics; but, despite the unnaturally severe loading thereby imparted, the guidance "worked beautifully." In fact so successful was this round that the guidance development schedule is reported to have been compressed. Included in the AX-11 series, and in a number of earlier programmes, were firings from a ship-motion simulator, from a near-vertical tube off Hunter's Point, from another submerged tube off San Clemente and from the first shipboard installation, constructed on U.S.S. *Observation Island*. Aboard this large surface vessel is a complete FBMS, which can handle evaluation of every part of the system except for underwater launching.

On July 22 the score during development flying was 24 successes, seven partials and two failures. On September 21, when a firing of a round almost indistinguishable from the operational Polaris started a new test series, the score was 27 successes, nine partials and two failures. Since that time one Polaris test vehicle has been fired every two to three weeks, and the 40 channels of information have provided data at the rate required for the development of the system as a whole. The test vehicles now being launched incorporate all the improvements stemming from the AX-11 series, and are programmed to fly 900 miles. Minor adjustments remain to be made in order to reach initial operational capability over a range of 1,200 n.m.

[*Continued overleaf*

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The basic carrier vehicle for the FBMS is a new class of giant submarine, with a submerged displacement of some 5,600 tons and nuclear propulsion giving global range and great underwater endurance at high speed. Each will be armed with 16 Polaris, which will be stored in vertical tubes aft of the conning tower, each sealed by a watertight cap opened shortly before firing. An automatic checkout and readiness system will continuously monitor the serviceability state of each round. The present ship-building programme authorizes nine of these great craft; six are under construction and three have been launched. The first is U.S.S. *George Washington*, and in it all the elements of the FBMS will be put together late in 1960, to achieve initial operational capability seven years ahead of the original target date. Meanwhile, refinements to the airframe and propellant are expected to confer an ultimate range of 1,500 n.m., and an unofficial report speaks of an AP-2 family of test vehicles for a Polaris with 3,000 miles' range.

Polaris: height, approximately 28ft (not 46 to 47ft as frequently reported); body diameter, 4ft 6in; launch weight, 28,000 lb; launch thrust, about 100,000 lb; design range, 1,200 nautical miles (1,382 miles); burnout and re-entry speed, about 8,000 m.p.h.

REDSTONE

U.S. Army; the missile is M5 (SSM-A-14).

Medium-range ballistic missile for mobile deployment.

OUR issue of May 23, 1958, contained an extensive appraisal of this impressive missile, together with a detailed cutaway drawing. Basing their work on the German A.4 (V-2) the Army Ballistic Missile Agency began to evolve Redstone in 1950. Features of the missile are aircraft-type construction, propulsion by a single Rocketdyne A-6 engine (which follows the pre-gimbal formula in having a fixed chamber and refractory jet-deflectors), integral tankage for liquid oxygen and alcohol, and a large separable re-entry body. The latter houses the Ford Instrument inertial guidance system, which controls the trajectory during re-entry via small wedge-section fins. The nuclear or conventional warhead is housed beneath a pointed nosecone.

A Redstone battalion has some 600 men and all the hardware is mounted on wheels. When the three main parts of a missile—thrust section, tankage and warhead/guidance—have been bolted together, the complete Redstone is erected by cables passing over A- and H-frames. Since August 1953 at least 45 Redstones have been fired at White Sands and Cape Canaveral. Five have been fired by user battalions, and the 40th Field Artillery Missile Group (Heavy) is now deployed in Western Germany. Redstone has also done valuable work as the basis of the Jupiter C space booster, and additional Redstones are to serve as boosters in the Mercury programme.

M5 Redstone: height, 63ft; body diameter, 5ft 10in; fin span, 12ft; launch weight, 61,000 lb; launch thrust, 75,000 lb; design range, 200 miles; burnout speed, about M 5 (3,300 m.p.h.).

SERGEANT

U.S. Army.

Tactical ballistic missile for mobile deployment.

OWING to its early inception, the Corporal system (page 511) falls far short of the optimum which can today be achieved. This is particularly true of its complexity, poor mobility, long reaction time and inability to function except from favourable terrain and in reasonably good weather. All these defects promise to be remedied by the Sergeant system, which, like Corporal, is the brain-child of the Jet Propulsion Laboratory of the California Institute of Technology. JPL has technical responsibility for the development of the complete weapon system. Sergeant was conceived some five years ago, and early in 1956 the Sperry-Rand Corp. received a prime contract from Redstone Arsenal for the manufacture of the production hardware. The latter work involves assembly and test of the complete missile and manufacture of the erector/launcher and the servicing, handling and maintenance equipment, and it is based at the Corporation's Utah Engineering Laboratory outside Salt Lake City.

Many of the advantages of Sergeant stem from the fact that it employs a solid propellant; a polysulphide material is used, cast by Thiokol. The airframe is a simple cylinder, fabricated from high-strength steel. At its rear end are four fins carrying trailing-edge control surfaces and refractory vanes for jet deflection. When operationally deployed, the erector/launcher is used to position the missile precisely in azimuth, and the desired trajectory is then achieved by feeding in a programme to the lightweight inertial system, which, by means of the surfaces already mentioned, governs the trajectory in pitch. A variety of conventional or nuclear warheads may be carried, contained beneath a pointed metal nosecone bolted to the guidance package, which in turn is attached to the front of the motor section.

Unlike Corporal, the Sergeant weapon system is air-transportable. According to the Department of Defense the system "is invulnerable to any known enemy countermeasures . . . has great mobility, can be more easily stored and put into action more quickly . . . and can be rapidly emplaced and fired under all conditions of weather and terrain, by a comparatively small crew." The external configuration of the missile itself has changed appreciably during the past three years, but the definitive weapon is now in production and was demonstrated for the first time on October 8 at Aberdeen proving grounds. Appropriation for the current Fiscal Year is $41.3m, and operational capability should be achieved within a few months.

Sergeant: height, 34ft; body diameter, 2ft 7in; fin span, 5ft 11in; launch weight, about 11,000 lb; launch thrust, 50,000 lb; design range, 75 miles; burnout speed, about M 3.5 (2,300 m.p.h.).

SOVIET BALLISTIC MISSILES

APART from the startling demonstration of engine power and guidance capability by recent Russian spacecraft practically nothing seems to have been learnt during the past year on missiles in this category. All that was then known was contained on page 879 of our 1958 Missiles issue. Almost the only relevant item which can be added is that on June 15 last *Aviation Week*, an American contemporary, suggested that a Russian fleet ballistic missile system was operationally deployed in the Atlantic. According to the American publication the conning tower of the 300ft submarine contains 4ft-diameter ports for a pair of launching tubes.

THOR

Royal Air Force (Bomber Command) and U.S. Air Force (Strategic Air Command); the missile is Strategic Missile 75, and it forms part of Weapon System 315A.

Intermediate-range ballistic missile for deployment from fixed soft installations.

AN exceptionally full account of the entire background to WS-315A was published in our 1958 Missiles issue (pages 862-872) and a description of the missile itself with a cutaway drawing appeared in our issue of May 22. Sponsored by the U.S. Air Force as a crash programme on December 27, 1955, Douglas Aircraft as the prime contractor took a number of calculated risks and thereby achieved the incredible feat of firing the first round 13 months later, on January 25, 1957. Moreover, WS-315A was an integrated weapon system from the outset.

The following are the major features of the SM-75 missile, starting at the bottom. Propulsion is provided by a gimbal-mounted Rocketdyne MB-2 (LR79), drawing liquid oxygen and RP-1 fed by turbopump from the tanks above. Flanking this engine are twin Rocketdyne vernier motors which stabilize the missile in roll and provide close control of the final trajectory. From the nozzle of the main engine to the transition ring, a distance of 62ft 4in, practically the entire airframe is monocoque propellant tankage built up from slabs of machined and chemically etched aluminium alloy. Use of this material renders the airframe sufficiently rigid for it to be mounted on its transporter/erector from supports at either end, without internal pressurization. Above the tank is the bay housing the 500 lb all-inertial AChiever guidance system by the AC Spark Plug Division of General Motors. Finally comes the thermonuclear warhead, of about 4 MT yield, protected by a G.E. Mk 2 heat-sink nosecone. The latter is probably the only heat-sink cone to see service, and it suffers from impacting subsonically and weighing 1,450 lb. It is stabilized—and prevented from re-entering the atmosphere backwards—by air gas jets, controlled by photocells which sense the horizon and a Sun-seeker against roll.

Produced by Food Machinery, the transporter/erector is a rigid trailer on which the missile may be air-lifted and finally towed to the launch emplacement. The tug is then uncoupled and the transporter/erector elevates the missile to the vertical position on its launcher base. All Thors are at present installed in soft complexes. Reaction time is 15 min. during which the environmental shelter is

First illustration of the definitive Sergeant, on its mobile erector/launcher

rolled aside, the missile is erected, the transporter/erector is lowered, the umbilical mast is plugged in, the propellant tanks are purged and then filled from ground storage (under helium or, outside the U.S.A., nitrogen pressure) and the automatic countdown and launch sequence is completed.

At the end of August 61 rounds had been fired (43 successfuls, 10 partials and 8 failures), of which 19 were non-military tests in the Discoverer, Thor-Able and Pioneer programmes. Certain of the latter had test objectives—such as in-flight photography and capsule recovery—which went beyond the design reliability of the missile. Testimony given at the start of Fiscal Year 1960 said that current production by Douglas, Santa Monica, of 120 missiles would equip five squadrons, of which "at least four" would be R.A.F. Each squadron should maintain 15 missiles at the T-15 min readiness condition, their emplacements being spaced 20 to 25 miles around the squadron headquarters. The first unit to be equipped was No. 77 Sqn., with headquarters at Feltwell, where five pads must now have completed some thousand countdowns. Several R.A.F. squadrons are now rapidly approaching operational capability.

As a sound basis for development, Thor is used in several space programmes and the possibility of putting it in a hard emplacement is also being pursued actively by Douglas (apparently privately). Douglas are also said to have proposed Thoric, in which an added second stage confers a 6,500-mile range.

SM-75 Thor: height, 65ft; body diameter, 8ft; launch weight, 110,000 lb; launch thrust, over 150,000 lb; design range, 1,500 nautical miles (1,727 miles); burnout and re-entry speed, 10,000 m.p.h.

TITAN

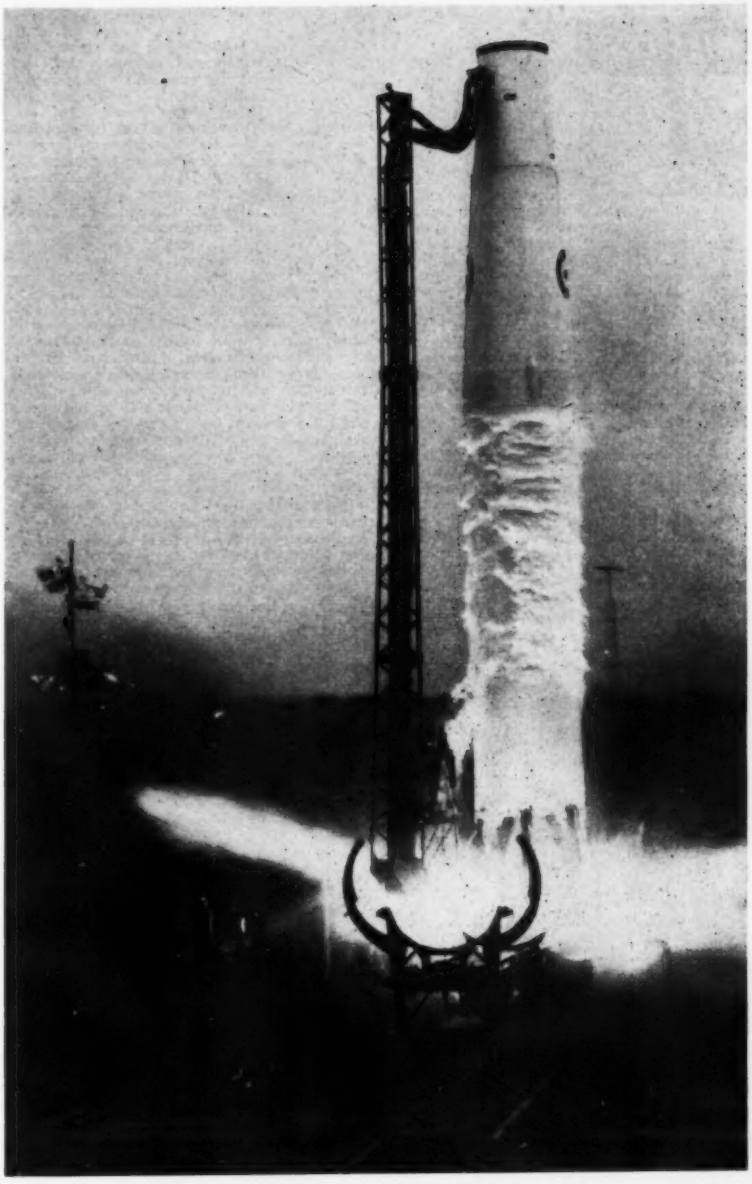
U.S. Air Force (Strategic Air Command); the missile is Strategic Missile 68, and it forms part of Weapon System 107-A-2.

Intercontinental ballistic missile for deployment from fixed hard installations.

IN 1953 the Strategic Missiles Evaluation Committee, under Dr. John von Neumann, recommended that an additional ICBM programme should be established as a back-up to Atlas. Following a development schedule roughly a year behind that of the earlier ICBM, the Titan weapon system WS-107-A-2 has since benefited from a vast amount of additional knowledge and later techniques. These have enabled its sponsors to adhere to a relatively tight schedule, notwithstanding the fact that the basic specification is exceptionally demanding, particularly in the matters of payload and range. In October 1955, the prime contract for design, fabrication and testing of the complete weapon system was placed with the Martin Company. Their contract is today valued at $384m, and the company created a new division near Denver, Colorado, specifically to handle this enormous programme. Overall systems integration is managed by Space Technology Laboratories, under the authority of the Ballistic Missile Division of the U.S.A.F. Air Research and Development Command.

Not only does Titan differ from Atlas in being a later concept, but also—and as a direct result, in view of later developments in starting large rocket engines *in vacuo*—it has a different configuration, the second stage being separated above the atmosphere. Both stages are monocoque cylinders, which when connected produce a vehicle with an overall height of some 99ft. This is greater than that of any other Western weapon before or since, and will be exceeded only by future spacecraft.

Both the first and second stage are manufactured from axial planks of copper-rich aluminium alloy. They are integrally machined and chemically etched, and are assembled by a technique of heliarc-fusion welding that required patient development. The first-stage tank has a diameter of 10ft and a length of 54ft, and when completed it houses liquid oxygen and RP-1 which are fed by turbopump to the first-stage engine. The latter is the Aerojet-General LR87, which has twin chambers side-by-side giving an aggregate sea-level thrust of 300,000 lb. The first production LR87 was delivered from Sacramento in November 1957. Gimballing of the main chambers provides control in pitch and yaw; rolling is governed by the turbopump gas-generator exhaust.



The first Thor to be fired by an R.A.F. crew (Vandenberg, mid-April)

At the appropriate time an automatic programming unit shuts down the first stage and fires four explosive bolts which joint it to the second stage. The latter is at present located in the lower unit by a series of axial channel sections, each 5ft in length, which are rigidly secured to the top of the first stage and carry the second in a low-friction system of recirculating balls. After a pre-computed coasting period, the gas-generator for the second-stage turbopump is started and its exhaust is pumped through four vernier motors disposed around the base of the second stage. This thrust then effects a clean separation, following which the second-stage engine is fired. The latter is the Aerojet-General LR91, and it has a single gimbal-mounted chamber giving a rated thrust above the atmosphere of 80,000 lb (67,000 lb at sea level). Like the LR87, it operates on liquid oxygen and RP-1, and the complete second stage, including nosecone, measures 8ft in diameter and 37ft in length.

When the correct final velocity has almost been reached the second-stage engine is shut down, but the gas-generator continues to run and exhaust through the four verniers. At the final velocity, the exhaust is diverted from the verniers to forward-facing nozzles in order to pull the second stage back from the warhead. The latter is larger than in any other Western ballistic missile. Unofficial reports state that Titan was designed to carry a payload of 6,000 lb, and further accounts allege that the yield of the largest warhead is 7 MT.

Since 1955 the contractor for the nosecone has been Avco, at Lawrence, Mass. Their original contract was for $140m, with which they developed a blunt, semi-ellipsoidal assembly pressed from stainless steel and coated with nickel. However, in view of the high deceleration and other disadvantages of the heat-sink type of nosecone, Avco's Research and Advanced Development Division were last August awarded a further $73.36m contract for a more slender and pointed cone, which can "tolerate higher temperatures, give a quicker re-entry to beat defences, have improved aerodynamic stabilization and more

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reliable sub-systems." No information is yet available on the stabilization system for the new cone, but the current blunt model is controlled during re-entry by the Darac system, which comes into action at an altitude of 300,000ft. Small rate-gyros sense angular acceleration about all three axes, and control the escape of bottled helium through a piping system which surrounds the cylinder containing the warhead and finally exhausts through four small nozzles disposed around the rear periphery of the re-entry body.

So far nothing has been said of the guidance system. In view of its late inception, Titan was planned from the outset for all-inertial guidance, and American Bosch Arma developed an entirely new system reported to weigh only 350 lb. Associated with it was a radio-inertial system, used during the first 300 sec of flight, developed jointly by Bell Telephone Laboratories and Remington Rand, whose Univac Division developed a remarkable digital computer which flies with the missile. Last year the critical decision was taken to incorporate the complete Bosch Arma inertial system into the Atlas ICBM, and since that time the only guidance available to Titan has been the interim radio-inertial system. This provides command control of trajectory up to the point of second-stage vernier cut-off, and although very accurate is open to countermeasures and precludes salvo firing.

However, WS-107-A-2 is too attractive to be compromised by such guidance and it will eventually go into service with a pure inertial system even more advanced in concept than that developed by Bosch Arma. The new system is being developed by the Instrumentation Laboratory of the Massachusetts Institute of Technology. It incorporates a miniaturized digital computer by IBM, and the sub-contractor for production will be AC Spark Plug.

Martin's Denver Division is the largest completely integrated missile plant in the Western world. Ground was broken on February 6, 1956, and the complete plant was occupied one year later. In the test area are four captive-firing stands. In the first of these is installed a "battleship" missile, in which the complete tankage system is exactly reproduced in heavy-gauge stainless steel. Further stands house the first and second stages of the actual missile. In sequence-firing, the two stages are mounted side-by-side and fired in series to simulate a complete mission. In tandem-firing the second stage is assembled above the first in order to evaluate the overall compatibility of the two stages. To an unusual extent Martin have attempted to eliminate all possible malfunctions before missiles leave the plant.

Nevertheless the first Titan to fly (missile A-3) malfunctioned in an unanticipated manner on February 3 last. By noon on the following day an exact duplication of conditions in a laboratory in Denver produced the same malfunction, and that night an answer was transmitted to Cape Canaveral. Finally, three years to the day from breaking ground at Denver, A-3 lifted from Pad 15 at Cape Canaveral and flew. A-3 was intended to investigate first-stage operation only, the second-stage tankage being filled with water. It was the first Western ballistic missile to achieve every test objective on its first flight. Titan A-5 flew successfully on February 25, and on April 3 the first Titan to be sent to Cape Canaveral (missile A-4, which twice malfunctioned the previous December and was returned to Denver for repair) achieved a very successful mission. Then on May 4 A-6 achieved the first separation of the second stage, the latter being equipped with a pair of external solid motors to push it ahead cleanly.

At the time of writing, the last Titan to be counted-down at Cape Canaveral exploded spectacularly on the pad. The date was August 14 and the failure was ascribed to premature and accidental release of the launcher hold-down clamps. The Titan is locked to its launcher by four A-frames disposed at 90 deg around the base of the first stage. After first-stage ignition these clamps hang on to the missile for six seconds, during which the systems are finally checked and the umbilical connections are broken. On August 14 the clamps let go after only one second; the missile rose some 10ft whereupon the main umbilical connections initiated a malfunction signal which cut off propulsion. The missile fell back to the pad and exploded.

From the outset Titan will be installed in hard underground silos. Each launch emplacement is centered about a pit 163ft deep and 40ft in diameter, within which is contained a 155ft tube of smaller diameter, housing the missile in a vertical attitude with both stages joined. The excavation will have a depth of 14 storeys and will contain an elevating system which will hoist the launcher and missile to the surface for firing, together with additional elevators for personnel and equipment. Adjacent to the main silo will be subsidiary pits containing the propellant-loading and equipment-storage facilities, the former 47ft deep and 37ft 6in in diameter and the latter 62ft deep and 40ft in diameter. Both will be separated from the missile silo by some 40ft of earth, and will be connected by air-conditioned tunnels so that the emplacement can sustain itself and function independently.

A complete SM-68 squadron will normally comprise nine such complexes, several hundred feet apart. Additional base equipment will include three storage silos, 73ft deep and 27ft in diameter, three spherical control centres with a radius of 51ft, three spherical powerhouses with a radius of 62ft, and six terminals for the BTL radar system each 68ft deep and 27ft in diameter. The firing silos are divided into three groups of three, each with its own control centre and ground guidance system. Automatic filling of the propellant tanks will be done with the missile underground, so that the actual firing may be accomplished very shortly after the launcher reaches the surface.

At the time of writing, five Titan squadrons have been named, at the following A.F.B.s: Lowry, Denver, Colorado; Ellsworth, South Dakota; Mountain Home, Idaho; Larson, Washington; and Beale, Cal. Chief contractor for launching equipment is American Machine and Foundry, whose contracts for Titan now exceed $100m. Each Titan base is programmed for completion in 20 to 24 months from the contract award, and base construction costs for digging the nine or ten silos (some bases will have one spare) and laying the reinforced concrete varies between $42m and $47m. Each missile costs rather more than $2m, and to this must be added the following costs for each squadron: launchers, $19m; radio-inertial guidance, $14m; propellant-loading systems, $9m; automatic checkout, $4m; communications and fire control, $1m; and transportation and handling equipment, $350,000.

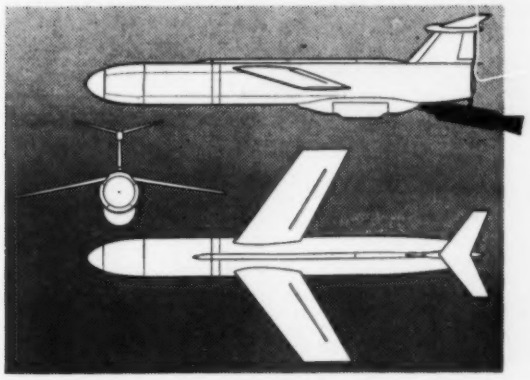
Initial operational capability with SAC is scheduled for the beginning of 1961. Development work is continuing on the basic missile with a view to achieving a storable liquid-propellant system. An unofficial report states that a range of 9,500 n.m. could be achieved with a high-energy second stage.

Launch from Cape Canaveral of Titan A-6, on May 4 of this year

SM-68 Titan: height, 90ft 6in; body diameter, 10ft (second stage, 8ft); launch weight, 205,000 to 218,000 lb; launch thrust, 300,000 lb; design range, more than 5,500 nautical miles (6,333 miles); burnout and re-entry speed, more than 16,000 m.p.h.

SURFACE TO SURFACE

Aerodynamic Cruise



Martin TM-76 Mace (length 44ft, to scale with other drawings on this page and p. 518)

GOOSE

ALSO known as Bull Goose, this diversionary and decoy vehicle was a development by Fairchild. Notwithstanding an exceptionally auspicious start to the flight-test programme, changing requirements caused its cancellation on December 12 last.

MACE

U.S. Air Force (overseas deployment); the missile is Tactical Missile 76A.

Subsonic-cruise bombardment missile for deployment from mobile bases.

DEVELOPED from the earlier TM-61 Matador, the TM-76 Mace is a far more effective weapon. Compared with its predecessor it can carry a larger payload (both fuel and warhead) and has a choice of two self-contained guidance systems, either of which gives much greater operational flexibility and virtual immunity from jamming. Developed and manufactured by the Baltimore division of The Martin Company, Mace went into production in the summer of last year and became operational in June last.

The airframe is fabricated largely from metal-honeycomb sandwich, and is shipped as a number of packaged sections for assembly by field units. It is launched by a Thiokol booster of approximately 100,000 lb thrust, and cruise propulsion is provided by an Allison J33-A-41 turbojet rated at 5,200 lb thrust. Any of a variety of nuclear warheads may be carried. Guidance in the TM-76A is the Goodyear Atran system, which scans the landscape electronically and compares it with a film-strip carried on board. In TM-76B an AChiever inertial system is used, produced by AC Spark Plug Division of General Motors.

Mace can be launched from fixed hardened sites. Alternatively it can be fired from a Goodyear-built Translauncher, towed by a Teracruzer made by Four Wheel Drive Auto Co. The complete system may be air-lifted and every portion is carried on these two types of vehicle. Mace can approach a target from any altitude and direction and take evasive action; it is impervious to electronic countermeasures, has true all-weather capability, can carry highly effective warheads and has "a very satisfactory degree of terminal accuracy." With a first cost, complete with Government-furnished engine, guidance package and booster of approximately $250,000, Mace is the cheapest missile per mile of range currently available. According to the Deputy Commander of the 9th Air Force, Mace "is probably the least complex missile in our inventory . . . and also probably the most reliable."

Mace was removed from the Budget by the House of Representatives this summer, but late in July, at the request of the Department of Defense, it was conditionally put back in the inventory. The first Mace (TM-76A) unit to become operationally effective is the 38th Tactical Missile Wing, whose three Groups occupy a number of NATO bases in Western Germany. At least one other wing is likely to receive the more advanced TB-76B, and it has been suggested that Mace units will be formed by Western Germany and Japan.

TM-76 Mace: length, 44ft; wing span, 22ft 11in; launch weight (without boost motor), 14,000 lb; design range, over 650 miles; cruise speed, 650 m.p.h.; cruise altitude limits, 40,000 down to under 1,000ft.

MALAFACE

French Navy.

Command-guided bombardment missile.

DESIGNED for the Aéronavale by Latécoère, Malaface has a somewhat dated "aeroplane" configuration, and is launched from a ramp mounted on the deck of a surface ship. Roughly 21ft in length, it is launched by a jettisonable boost motor and thereafter has a range of up to 25 miles on the thrust of its acid/furaline sustainer. It is guided by radio command and carries a large conventional warhead. Numerous test firings have taken place.

MATADOR

U.S. Air Force (overseas deployment); the missile is Tactical Missile 61.

Subsonic-cruise bombardment missile.

A FULL history and description of this well-known weapon—the first "pilotless bomber" since the notorious "V-1"—was contained in our 1957 Missiles issue. Approximately 1,200 Matadors were delivered before production by The Martin Company was switched to the more advanced Mace.

REGULUS 1

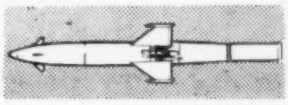
U.S. Navy; the missile is SSM-N-8.

Subsonic-cruise bombardment missile for launching from submarines and surface vessels.

ALTHOUGH relatively early in conception and modest in performance, Regulus 1 has proved to be so trouble-free during extensive flying of recoverable test vehicles and operational versions that it is today deployed as an operational missile with the U.S. Navy. Initial operational capability was achieved in May 1954 and the last of 514 was delivered in 1958. Virtually a pilotless aeroplane, Regulus 1 is launched by a pair of 66,000 lb-thrust boost motors, either from a launching rail or from an expendable trolley (which can be used on a carrier deck). Quite a large nuclear warhead may be carried, and the weakest link in the system is the radio-command guidance. Currently Regulus 1 is scheduled to remain in the inventory for at least two more years. It is deployed aboard four cruisers and four conventionally powered submarines.

Regulus 1: length, 33ft 8in; wing span, 21ft; launch weight (without boost motor), 14,000 lb; design range, 500 miles; cruise speed, 600 m.p.h.

A TM-76A Mace of the 38th Tactical Missile Wing, U.S. Air Force, on its Translauncher



Robot 315

REGULUS 2

U.S. Navy; originally the missile was SSM-N-8.

Supersonic-cruise missile.

NOTWITHSTANDING its excellent performance and outstandingly successful development programme, the contract for Regulus 2 was cancelled last December. Details were given in our issue of December 5, 1958. The production missiles in the manufacturer's hands at the time of the cancellation are being modified to the KD2U-1 drone configuration to serve as targets for U.S.A.F. Bomarc missiles.

ROBOT 315

Royal Swedish Navy.

Air-breathing bombardment missile for launching from destroyers.

AN outline history of Robot 315 was contained on page 880 of our 1957 Missiles issue. As the drawing above indicates, there are cruciforms of delta wings and nose-mounted control fins. Launching is effected at a shallow angle under the thrust of four inbuilt solid boost motors, and cruise propulsion is provided by a form of resonant duct. All-weather guidance is fitted, and 315 is certainly large enough to carry a nuclear warhead. Firing trials from a destroyer began in April 1955, and two such ships are today in service with this missile.

Robot 315: length, 24ft; wing span, 7ft; firing weight, 3,000 lb; design range, at least 10 miles; cruise speed, high subsonic.

SLAM

Study by U.S. Air Force.

Nuclear-powered cruise-type missile.

NAMED from the initial letters of its category —supersonic low-altitude missile—this startling concept postulates a vehicle, supported either by body-generated lift or by an abbreviated wing, powered by a nuclear ramjet and capable of delivering nuclear weapons "anywhere on the globe with extreme accuracy." Recently Lt-Gen. Roscoe C. Wilson said: "We are studying presently a new approach through the supersonic low-altitude missile. This will be powered with a nuclear ramjet and will have almost unlimited range. Defence against this type of weapon appears technically extremely difficult for the foreseeable future."

It appears that Slam is a family of related weapons. An intense competition for the study contract involved such firms as Convair (with

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a project named Big Stick) and North American (with Bolo), but Chance Vought won it late in September. So enthusiastic was this company that they injected a substantial amount of their own money on top of the original study contract, and a company spokesman recently said he was convinced of the feasibility of such a missile and of its value as an under-the-radar deterrent. An unofficial report claims that Chance Vought's proposal involves a guidance system known as Fingerprint, in which terrain data are fed in before take-off and compared with the ground beneath the missile. The propulsion system stems from Project Pluto, in hand by the Livermore Laboratory of the A.E.C., Marquardt and N.A.A. International.

SNARK

U.S. Air Force (Strategic Air Command); the vehicle is Strategic Missile 62A.

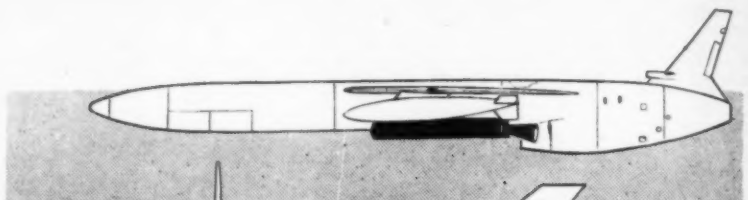
Intercontinental, air-breathing, cruise-type missile

IN several respects Snark is unique. Virtually a pilotless bomber, it carries an exceedingly large thermonuclear warhead and was the first unmanned delivery system capable of carrying such a load over an intercontinental range to become operational. It is the outcome of a decade of effort by Northrop Aircraft (now the Norair Division of Northrop Corporation). For more than four years it was far from certain that it would be placed in the SAC inventory at all, but its operational flexibility earned it a production contract, albeit a limited one. Unlike any ballistic weapon currently conceived, Snark can take-off from its base in the U.S.A., fly 5,500 n.m. and then enter a target area at any altitude and from any direction, finally impacting with extreme accuracy.

A full history was published in our 1957 review issue (December 6). Essentially the missile consists of an airframe which is conventional except for the fact that there is no horizontal tail, control in pitch being provided by elevons. After launching by a pair of boost motors—each of which provides 130,000 lb thrust and is equipped with jetavators to control the initial trajectory—Snark climbs away on the power of its Pratt & Whitney J57 turbojet, which draws JP-4 fuel from internal tanks (21,000 lb) and jettisonable tanks under the wings (5,000 lb). Inertial guidance by Nortronics is employed, although owing to the considerable flight time (possibly 11 hr) the stable platform is periodically monitored by a star-tracker. Guidance weight is fairly high, at some 750 lb. At the correct point the missile is programmed to dive on to its target, the warhead being separated to fall supersonically while the remainder of the vehicle pitches up with such violence as to suffer structural failure (thus incidentally forming additional spurious radar targets). Warhead yield is reported to vary up to 20 MT.

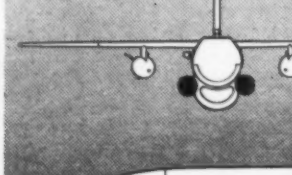
During 1958 several Snarks were fired successfully down the Atlantic missile range, and on one occasion a missile flew 1,300 miles to a pre-programmed point and then returned to land on Cape Canaveral's runway. The decision to place Snark in SAC's inventory was taken in April 1957. The first squadron (556 Strategic Missile Sqn.) was activated in December 1957 and is now fully equipped with 15 missiles and 740 men at Presque Isle A.F.B., Maine. The unit fired the first representative production Snark on a 5,000-mile mission on April 7 last, and is expected to become fully operational at the end of the calendar year. If necessary a Snark squadron can operate in a mobile rôle, although the fact that, with its missile, the 16-wheel launcher weighs 90,000 lb restricts its cross-country performance.

SM-62A Snark: length, 67ft 11in; wing span, 42ft 3in; launch weight (with boosters), 59,936 lb; design range, 5,500 nautical miles (6,333 miles); cruise speed, M 0.93 (615 m.p.h.); altitude limits, 50,000 down to 1,000ft.



Northrop SM-62A Snark

Sud 4200



SUD 4200

French Army.

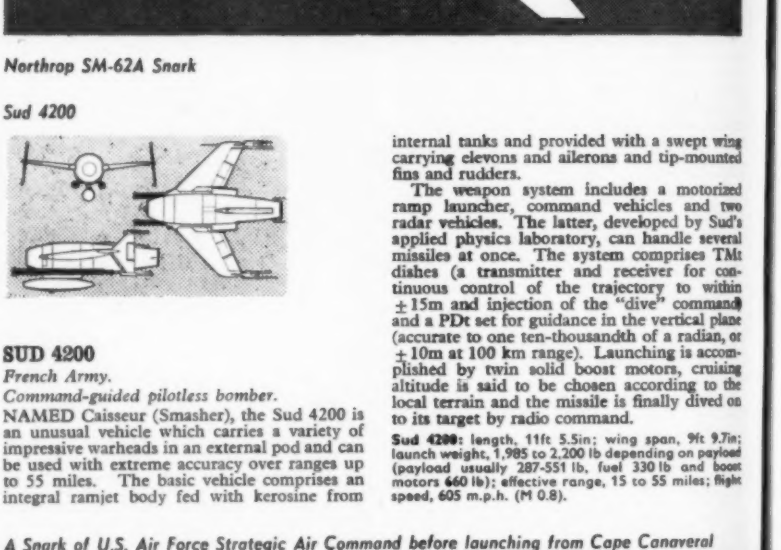
Command-guided pilotless bomber.

NAMED Caisseur (Smasher), the Sud 4200 is an unusual vehicle which carries a variety of impressive warheads in an external pod and can be used with extreme accuracy over ranges up to 55 miles. The basic vehicle comprises an integral ramjet body fed with kerosine from internal tanks and provided with a swept wing carrying elevons and ailerons and tip-mounted fins and rudders.

The weapon system includes a motorized ramp launcher, command vehicles and two radar vehicles. The latter, developed by Sud's applied physics laboratory, can handle several missiles at once. The system comprises TM: dishes (a transmitter and receiver for continuous control of the trajectory to within ±15m and injection of the "dive" command) and a PDt set for guidance in the vertical plane (accurate to one ten-thousandth of a radian, or ±10m at 100 km range). Launching is accomplished by twin solid boost motors, cruising altitude is said to be chosen according to the local terrain and the missile is finally dived on to its target by radio command.

Sud 4200: length, 11ft 5.5in; wing span, 9ft 9.7in; launch weight, 1,985 to 2,200 lb depending on payload (payload usually 287-551 lb, fuel 330 lb and boost motors 660 lb); effective range, 15 to 55 miles; flight speed, 605 m.p.h. (M 0.8).

A Snark of U.S. Air Force Strategic Air Command before launching from Cape Canaveral



SURFACE TO SURFACE Battlefield

BANTAM

Swedish Armed Forces.

Wire-guided missile for use by infantry.

DEVELOPED by the renowned Swedish armaments company of A.B. Bofors, the Bantam is intended for use by individual foot-soldiers operating in adverse terrain, possibly thickly covered in snow at temperatures well below freezing. The airframe is constructed almost entirely from glass-reinforced plastic laminates. The weapon is carried in a rigid box with each of its four wings folded about an axial hinge near mid-span. To fire the missile the box may be rested on the ground at the required angle or, in exceptional circumstances, it may be held at the hip. The missile leaves the box under the boost charge of its two-stage motor, and the fact that each outer wing has conical camber first unfolds the wings and then causes the missile to roll during flight. Control is effected by trailing-edge trembler spoilers. A large number of test firings has now taken the weapon to an advanced stage, and Bantam is going into production for the Swedish Army and will also be made available for export.

Bantam: length, 31.5in; wing span, 15.75in; firing weight, 13.2 lb; effective range, up to 6,600ft; flight speed, probably about 200 m.p.h.

Bo 810

West German Army.

Wire-guided missile for use by infantry.

ORIGINALLY known as Cobra, the Bo 810 was designed by Bölkow-Entwicklungen as a replacement for the S.S.10, having the same lethality in a simplified weapon system including a lighter and smaller missile. Careful development during the past five years has brought the system to an operational stage. The missile carries a shaped warhead which weighs but 8.8 lb, yet is claimed to pierce 21in of armour when impacting perpendicularly. Velocity-type control is exercised via a simple command box. Although developed largely as a private venture, the 810 is today in full production for the German government; and presentations have been made on behalf of the Federal Defence Ministry to most NATO nations.

Bo 810: length, about 42in; wing span, about 19in; firing weight (5.5 lb warhead),20.9 lb; effective range, 1,640 to 5,250ft; flight speed, 190 m.p.h.

DAVY CROCKETT

U.S. Army.

Tactical nuclear delivery system for infantry.

FIRST officially mentioned in the budget hearings for Fiscal 1960, Davy Crockett is the smallest delivery system for a nuclear device yet to have reached the hardware stage. The warhead is a fractional-yield (sub-kiloton) device, unofficially said to resemble that being planned for an advanced version of Bullpup. Like Bullpup the Army weapon is being developed by the Orlando, Fla, Division of The Martin Company. Apparently the warhead is mounted at the forward end of a solid-propellant motor, the complete missile being fired from a bazooka tube which fits closely around the motor casing. Obviously considerations of safety for the operator imply a range of several miles; and even then it is doubtful if the warhead can be detonated up-wind of the launcher. No data on the hardware have been divulged, but the system is said to be designed for operation by two men.

Davy Crockett: length of launcher, probably about 8ft; length of missile, of the order of 5ft; diameter of motor, less than 6in; diameter of warhead, more than 6in (it is likely that the portability of the system will be determined by the minimum size of the nuclear device); effective range, not less than 2 miles.

FAIREY ATK

Under development for the British Army.

Advanced anti-tank weapon system.

TWO years ago it was announced that Fairey Aviation held a development contract from what was then the Ministry of Supply for a complete weapon system "designed to sweep the heavy tank from the battlefield." It is not possible to give any details of the weapon or its progress.

HONEST JOHN

U.S. Army and armies of Western Germany, Japan and other Western nations.

Spin-stabilized artillery rocket.

AN account of this fearsome missile appeared in our 1957 Missile issue. Essentially it consists of a 23in-diameter solid motor to the front of which can be attached any of a wide variety of 762 mm (30in) warheads, including a range of nuclear devices. It is used tactically to provide close support over ranges of several miles. Compared with artillery it can deliver far more destructive effect while having appreciably better battlefield mobility. It is aimed by steering its self-propelled launcher in azimuth and then elevating the launching ramp to achieve the desired range. At launching, spin motors behind the warhead initiate a rapid roll to ensure flight stabilization, which is thereafter maintained by the canted fins. Honest John was developed by Army Ordnance, and many thousands of rounds have been made by Douglas Aircraft and Emerson Electric.

M31 Honest John: length, 27ft 3in; fin span, 9ft 1in; body diameter, 23in (warhead, 30in); firing weight, 5,800 to 5,950 lb; design range, 12 miles (ultimate range, with reduced accuracy, is 30,000 yd, in a flight-time of 87 sec); burnout velocity, M 1.7 (1,250 m.p.h.).

LACROSSE

U.S. Army and Canadian Army; the missile is SSM-A-12.

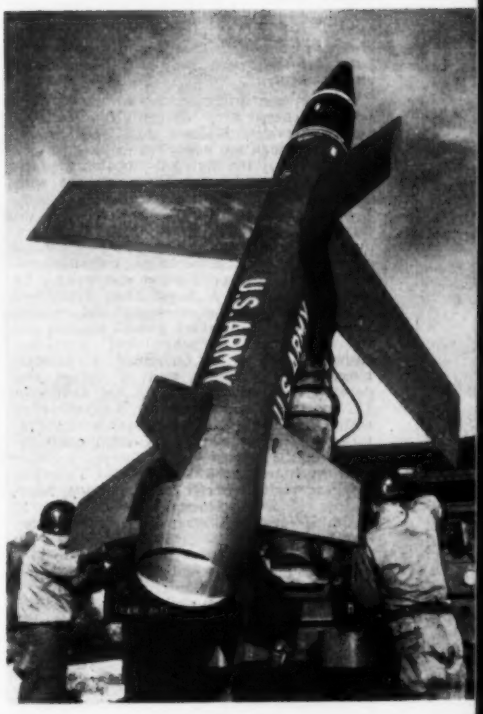
Guided artillery missile for mobile deployment.

AS was outlined in our 1957 Missiles issue, the Lacrosse system was sponsored by the U.S. Marine Corps and developed jointly by the Cornell Aeronautical Laboratory and the Applied Physics Laboratory of Johns Hopkins University. The Marine Corps will not now use the weapon, but it has been adopted by the U.S. Army and is in limited production by the prime contractor, the Orlando, Florida, Division of The Martin Company. Cornell are continuing development.

The vehicle itself comprises a simple cylindrical body fabricated from high-strength aluminium alloy, containing a solid-propellant rocket motor by Thiokol and to which can be attached a cruciform of swept wings of relatively high aspect ratio, a cruciform of movable tail fins indexed at 45 deg to the first, and a variety of warheads, including shaped charges and several nuclear devices. Fuzing and arming is accomplished by a G.E. system and the nosecone is by Solar.

All portions of the weapon system are mounted on wheels and can be air-lifted. The elements of the system comprise the missile, a zero-length launcher mounted on a standard 2½-ton truck and the fire-control system. The latter does not rely upon precise target data at the launch site but does need "data which can be supplied by a survey unit and externally generated information such as map co-ordinates." Lacrosse's close-support capability arises from the use of a mobile guidance station in the front-line. Guidance equipment, which can be carried in a jeep or divided into manually transportable packs, includes an angular tracker, a computer, a range and direction indicator and a power supply, together with a device for measuring the bearing and distance of the target. Like the game of Lacrosse, the missile can be passed from one operator to another. Once in the air it is acquired by the tracker, "flown" by the computer and finally dived into the target. Chief contractor for guidance is the Federal Telecommunications Division of I.T. & T.

Production Lacrosse missiles have been coming off the line at Orlando since August 1957. The first two battalions of the U.S. Army were activated during the first half of this year, and contracts awarded to Martin since January in order to support two further battalions amount to $25,181,000. By June 1958 1,000 rounds had been delivered and, although the Defense Department describe the missile's present status as "limited production," an unofficial report states that current output is about 280 per month. A year ago the Canadian Prime Minister announced the adoption of Lacrosse by the Canadian Army. For $1,198,000 one battery will be equipped with four launchers and 12 missiles and their associated equipment. Half the battery will be used for training purposes and the other will be deployed with the Army Brigade serving in Europe with NATO. Annual cost for re-supply of missiles will be $360,000.



Pre-launch check on a U.S. Army Lacrosse

M4E2 Lacrosse: length, 19ft 2.5in; wing span, 9ft; body diameter, 20.5in; firing weight, 2,300 lb; design range, limited by guidance, but usually not less than 8 miles; flight speed, transonic.

LITTLE JOHN

U.S. Army.

Spin-stabilized artillery rocket.

DURING the past five years this scaled-down Honest John has been subjected to a remarkable amount of development, considering the simplicity of the basic concept. Compared with the earlier missile it is much smaller; and the entire weapon system, including the lightweight launcher, can be brought into a front-line firing position by an H-34 helicopter (an H-37 is needed to lift Honest John).

Little John is at present the smallest battlefield delivery system for a nuclear warhead, although a variety of conventional heads may also be fitted. Unlike Honest John the missile does not roll for stabilization, but carries Hamilton Standard spin motors which drive gyros which in turn move the cruciform of tail controls. Training and development techniques are being studied by the 101st Airborne Division. Appropriation for FY60 is $38.5m.

XM51 Little John: length, 14ft 6in; fin span, 23in; body diameter, 12.5in; firing weight, 800 lb; design range, several miles ("comparable to medium and heavy artillery"); flight speed, supersonic.

MISSILES 1959...

MALKARA

Australian Army and British Army.

Heavy wire-guided missile for employment from vehicles, light naval craft and fixed emplacements.

THE only non-British guided weapon to have been purchased as a standard type for the British Services, Malkara is a large missile which, although too heavy for employment by infantry, offers the high kill-probability which is today deemed essential in combat with armoured vehicles. Moreover, its various warheads are larger than those which can be carried by any other missile in this category of which details are available, thus rendering it eminently effective in the general bombardment rôle. The specification was written by the U.K. Ministry of Supply, and it outlined the requirements for a simple and reliable weapon system, including ground support and test equipment, launcher and simulator. Although the R.A.E. retained a parental interest, the complete task of design and development was entrusted to the Australian Government Aircraft Factories, in collaboration with the Aeronautical Research Laboratories, and assisted by several other establishments of the Department of Supply, together with such companies as Bendix-Technico, Commonwealth Aircraft Corp., Dunlop, Ever-Ready, National Instrument Company, S. Smith & Sons, S. Skinner and Trimax Transformers. The M.o.S. in Britain managed the overall development of the vehicle and provided gyros and relays from British firms (the former coming from Reid & Sigrist).

From front to rear the missile comprises: any of a variety of types of warhead with a weight of some 60 lb; the square-section body, housing elements of the guidance system and the hydraulic servos which move the horizontal pair of wings for control in pitch and the vertical pair for control in yaw (the missile being roll-stabilized by differential movement of the vertical pair of wings); and the aftbody, containing the blast tube from the solid-propellant boost and sustainer motors and the fixed cruciform of tail fins which are indexed at 45 deg to the wings. Malkara is fired automatically from a zero-length launcher and is controlled throughout its flight through twin trailing wires, the ground control unit "providing the correctly shaped voltage through the wire in response to control-stick demands and incorporating the required checking and monitoring circuits." It is considered that the adoption of roll-stabilization increases the accuracy of guidance by achieving precise response to yaw and pitch demands.

It was early in 1954 that the general form of the weapon system was finalized, and test firings of fully controlled rounds began in November 1955. During the course of some hundreds of firings at Woomera and Puckapunyal the complete system has been brought almost to the operational stage, and its performance can be fairly described as outstanding. Last August Mr. Aubrey Jones, then British Minister of Supply, announced that 30 Malkaras had been sent to Britain for acceptance trials on the range at Kircudbright, and that 150 more were on order at a cost of some £A400,000 (£320,000). Like the tests in Australia, the British evaluation was a complete success, and last August 23 it was announced that Malkara was being procured in inventory quantity for the British Army. As things stand at the moment the Government Aircraft Factories are likely to manufacture some hundreds of rounds for the British Army, and appear to be strongly placed in seeking orders from many other countries (notwithstanding the fact that the Australian Army have not adopted the missile). It remains to be seen whether or not Malkara will displace the British-sponsored Fairey weapon, and whether the Australian missile will be manufactured in Britain.

Malkara Mk 1: length, 77.5in; wing span, 31.24in; maximum body dimension, 8in (circular or square, depending on station); firing weight, 206 lb; effective range, over 6,000ft (limited by guidance); flight speed, high subsonic.

MOSQUITO

Private venture by Swiss company.

Anti-tank missile for operation by infantry.

LIKE the majority of the weapons produced jointly by Contraves AG. at Zurich and the Oerlikon Machine Tool Works, Bührle & Co., Mosquito is privately financed and available to any purchaser. Essentially conventional, the missile has an airframe of incredibly light weight with a glass-fibre body and honeycomb-sandwich wings. The body houses a two-stage motor, and to it may be attached a 7.5 lb hollow-charge head (capable of piercing 21in of armour) or, for training purposes, a parachute box. An infantryman can carry a rigid container for two Mosquitos, which are readied for use by clipping on the wings and elevating the container to the desired angle by a collapsible rod.

After firing, the missile is controlled by a conventional optical line-of-sight system. Mosquito is roll-stabilized by a power-driven gyro. Its flight is controlled by vibrating spoilers on the four wings according to signals transmitted from the control joystick through three of the four wires of a small-diameter trailing cable. All the electronics are transistorized. An unusual feature is that the warhead is armed by a signal transmitted through the fourth wire, as a result of a deliberate action by the operator when the missile has flown beyond friendly troops.

Mosquito: length, 41.3in; wing span, 23.6in; body diameter, 4.7in; firing weight, 25 lb; effective range, 5,500ft; flight speed, 190 m.p.h.

P.V.

Private Venture by British Company.

Wire-guided missile intended for use against tanks, armoured vehicles and fortified emplacements.

SINCE the summer of 1955, Pye Ltd. has been privately financing the development of a missile known merely by the initials "P.V." The company's thinking has led them to produce what is believed to be the most lethal missile which can be designed within the maximum weight thought to be compatible with manual portability, and employment either from thin-skinned vehicles or dismounted. The company has enjoyed in some measure the co-operation of H.M. Government during the development of this project, which has now reached an advanced stage.

Conducted by a small but effective team of engineers, who were given an almost completely free hand, the development has been remarkably trouble-free. At an early stage a flight simulator was built, and this was used to conduct a fundamental investigation into the performance of the human operator when presented with the task of flying a line-of-sight missile. As a result of this, although always striving to minimize the necessary ground equipment, Pye have introduced a signal shaper which greatly reduces the skill necessary to guide the weapon. The missile itself has cruciform fixed wings, wrapped from sheet around a honeycomb core, and a two-stage motor—designed by Pye, manufactured by Bristol-Aerojet—which has incorporated in it a nozzle deflector system for steering purposes. It is designed to accept any of a number of types of warhead.

The missile is controlled from the ground with a thumb joystick, mounted in a pistol grip and connected to a control unit. This joystick is used, with or without binoculars, to keep the missile on the line of sight to the target. Although it is primarily intended for use from thin-skinned vehicles (six launcher/containers were shown mounted on a Land-Rover at this year's S.B.A.C. show), it can be dismounted and used by infantry with the launcher remote from the operator. Numerous rounds have been fired at Larkhill, and it is intended that guided rounds will be fired this year.

PV: length, 60in; wing span, 24in; body diameter, 6in ;firing weight, approximately 80 lb; performance classified.

SHILLELAGH

U.S. Army.

Close-support bombardment system.

ACCORDING to the U.S. Department of Defense "The Shillelagh is a lightweight missile system being developed for close-in support of troops. It will provide greatly increased firepower against armour, troops and field fortifications. In one application the missile will be vehicle-mounted. The weapon is expected to become operational in the mid-1960s." Development responsibility is vested in the Ordnance Tank Automotive Command, contract supervisor is the Army Rocket and Guided Missile Agency, and the development contract has been placed with the Aeronutronics Division of the Ford Motor Co. According to an unofficial report Shillelagh may be renamed "Pentomic." In turn Aeronutronics have chosen Raytheon to develop the fire-control subsystem, the complete guidance system being of a miniaturized electronic nature and including a computer. Total development cost of Shillelagh is put at $23m, and some $3m are being voted during the current fiscal year.

SOVIET MISSILES

IN the November 1957 Anniversary Parade through Red Square in Moscow three types of tactical ballistic missile were driven past, mounted on their tracked launchers. The smallest, said to be designated T-5C, is some 25ft in length and weighs about 3,000 lb, resembling an undernourished Honest John; it was mounted on the 1955 amphibious chassis. Next came a rather heavier version of the same general type, unofficially reported to be called T-5B. Some 30ft long, this missile appears to weigh about 5,000 lb and is operationally deployed on a JS.3 chassis, the rocket-motor being kept warm by a cylindrical housing on the elevating launcher. The largest of the Soviet battlefield weapons, and alleged to be called the T-7A, resembles Sergeant on a slightly smaller scale, but differs from the American weapon in being carried on a JS.3 chassis. Weighing some 10,000 lb, it probably has a range of about 50 miles and may well have inertial guidance.

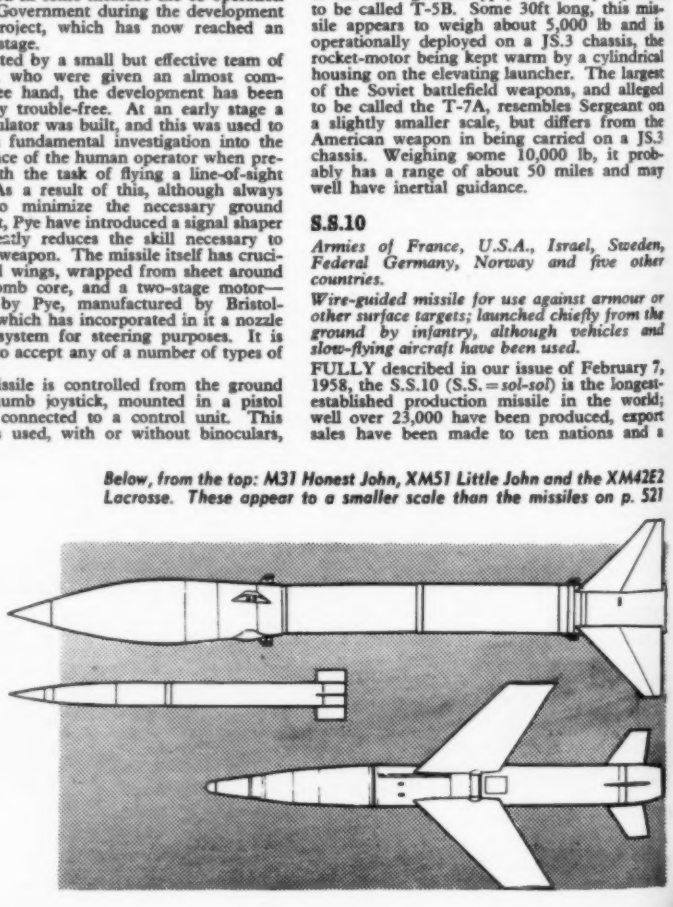
S.S.10

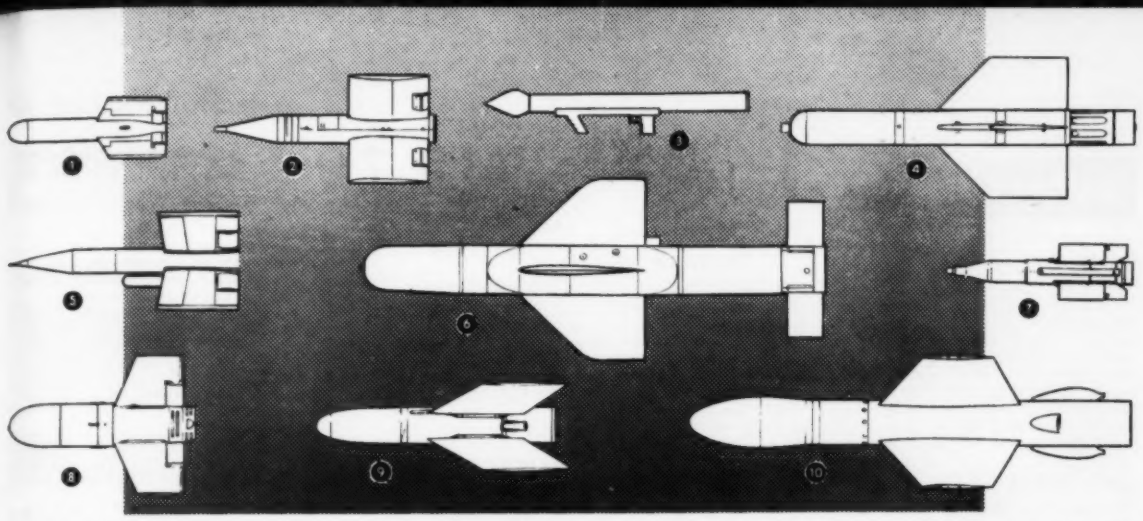
Armies of France, U.S.A., Israel, Sweden, Federal Germany, Norway and five other countries.

Wire-guided missile for use against armour or other surface targets; launched chiefly from the ground by infantry, although vehicles and slow-flying aircraft have been used.

FULLY described in our issue of February 7, 1958, the S.S.10 (S.S. = *sol-sol*) is the longest-established production missile in the world; well over 23,000 have been produced, export sales have been made to ten nations and a

Below, from the top: M31 Honest John, XM51 Little John and the XM42E2 Lacrosse. These appear to a smaller scale than the missiles on p. 521





Drawn against a tinted panel representing a width of 12ft are: 1, Bantam; 2, Mosquito; 3, Davy Crockett (provisional); 4, Pye PV; 5, Bo 810; 6, Malkara Mk 1; 7, Vigilant; 8, S.S.10; 9, S.S.11; 10, S.S.12. In the illustration opposite the tinted panel represents a width of 25ft.

number of rounds have been fired in anger (by Israel against Egyptian armour). The missile has the company designations of Nord 5202 (inert warhead, for training) and Nord 5203. Like its many later competitors, it carries a shaped charge on the nose of a cylindrical body; propulsion is by a two-stage solid motor, and the missile is lifted and steered by a cruciform of wings carrying trailing-edge vibrating spoilers (which, when their neutral point is offset according to signals transmitted from the operator through trailing wires, impart asymmetric drag to steer the missile).

S.S.10 can readily be used by infantry, but it is more often fired from jeeps, helicopters and other vehicles. The weapon system comprises the missile, transport/launcher box, control box (with joystick), signal generator, selection box (where multiple rounds are controlled by one operator), and binoculars. Additionally, Nord are prepared to supply a comprehensive electronic simulator.

With the standard 11 lb warhead, which can penetrate 16in of armour when impacting perpendicularly, the missile costs £280. Production is running at the rate of several hundred monthly. The largest single contract was that placed by the U.S. Army in the spring of this year. Valued at $7.5m it covered the cost of 1,000 rounds and was a straightforward purchase for the U.S. 7th Army and other NATO forces in Germany. Further batches may go to the U.S. Army in Korea and the new mobile Strategic Army Corps based in the U.S.A.

S.S.10 is also manufactured by the government-operated Direction des Etudes et Fabrications D'Armement as the Entac (Engin Tactique Anti-Chars). The DEFA Entac differs from the industry-built missile in minor respects only.

S.S.10 (Nord 5203): length, 33.86in; wing span, 29.53in; body diameter, 6.5in; firing weight, 33.07 lb; effective range, 5,250ft; flight speed, 180 m.p.h.

S.S.11

French Army, French Navy and (evaluation quantity) the British Ministry of Supply and U.S. Army; later the S.S.11 is likely to be used by most NATO nations and other countries.

Wire-guided tactical missile for use against armour and other surface targets; launched from the ground, from vehicles or slow-flying aircraft.

IN our issue of November 14 last, there appeared an extensive description of the complete S.S.11 weapon system. The missile itself is manufactured by Nord-Aviation as the Type 5210, and compared with the S.S.10 it has twice the weight, twice the range and rather more than twice the speed. It cannot be employed by infantry, but many hundreds of rounds have been successfully fired from all kinds of vehicles, aeroplanes and helicopters (*Flight*, September 18).

Owing to the much increased flight speed a new type of control has been chosen (first used on the Type 5103 air-to-air weapon), in which steering is accomplished by interrupting the jet from the rocket motor to produce asymmetric thrust. The booster charge issues through twin nozzles flanking a central nozzle for the sustainer motor. The deflectors vibrate like miniature windscreen wipers, and their neutral point is biased according to signals transmitted via trailing wires from the operator. The three types of warhead are the 125 AC shaped charge for anti-tank warfare, 140 AP fragmentation for anti-personnel use, or a dummy head for training. More powerful warheads are under development, and in all cases detonation is rendered impossible during the first four seconds of flight. Rounds have been fired from aircraft travelling at up to 250 m.p.h. Evaluation trials from Twin Pioneers have been conducted by the M.o.S. and large numbers have been supplied for evaluation to the U.S. Army (S.S.11 development has been partially financed by the U.S.A. under the MWDP).

S.S.11: length, 46in; wing span, 19.7 or 20.47in; body diameter, 6.46in; firing weight, 63-64 lb; effective range, 1,650 to 11,500ft; flight speed, increasing from 245 to 425 m.p.h. during flight.

S.S.12

French Army.

Heavy wire-guided missile.

A MOCK-UP of this formidable missile was displayed at the Paris Salon. Essentially the S.S.12 is a "stretched" S.S.11, having the same type of two-stage solid motor with jet deflectors to provide steering forces according to guidance signals transmitted from wire spools mounted on opposite sides of the aft-body. The bulged nose accommodates any of a variety of warheads, one version being described as "powerful enough to destroy any pillbox." Firing trials are in hand by Nord-Aviation and the French Army, and progress was described in June as "very encouraging."

S.S.12: approximate length, 75in; wing span, about 32in; body diameter, about 9in; firing weight, about 200 lb; effective range, several miles; flight speed, over 400 m.p.h.

TIGERCAT

Private venture by a British company.

Multi-purpose missile for battlefield use.

ESSENTIALLY Tigercat is a land-based version of the Seacat (page 528) ship-to-air weapon system developed for the Royal Navy by Short Bros. & Harland Ltd. No details of Tigercat have been divulged, but its external configuration appears to be identical with that of its marine progenitor and an essentially similar launcher, mounted on a tracked chassis and carrying four rounds, has been illustrated in a drawing (*Flight*, September 18, page 252). It may be, however, that a new form of guidance is employed, since in the centre of the four rounds could be discerned a convex bulge presumably forming a radome; and the fact that the development of Tigercat is being assisted by Elliott Bros. (London) Ltd. may well indicate guidance more sophisticated than that of Seacat. Tigercat is intended "to replace land artillery" and can be employed in surface-to-surface or surface-to-air rôles.

Tigercat: no details of this weapon have been released, but the dimensions of the closely related Seacat are, length, 57.85in; wing span, 25.6in; body diameter (round or square section, according to station), 7.5in.

UNDESIGNATED

Private venture by U.S. company.

Lightweight missile system for battlefield use.

SINCE early this year Chance Vought Aircraft have been making presentations to the U.S. Army of "a new lightweight surface-to-surface missile." According to the company it has been built up almost entirely from well tried hardware, and unofficial reports state that the entire system can be carried and operated by a single foot-soldier. Of four recent firings three are said to have been completely successful.

VIGILANT

Private venture by British company.

Small wire-guided missile for use against armour or other "hard" targets.

AN analysis of this exceptionally small missile was contained in our issue of May 22 last. A privately financed development by the guided weapon department of Vickers-Armstrongs (Aircraft), the V.891 Vigilant is intended for operation by an unaided foot soldier, and great emphasis was placed on minimizing size and weight. Development began in July 1956 and the programme has since been financed at a substantial rate.

In flight Vigilant is made to roll slowly, and its guidance is of the velocity-type in which a given movement of a thumb-stick produces a proportionate change in flight direction. From front to rear, features of interest include a nose probe (retractable in early development rounds), a fuze for a hollow-charge warhead, a cordite-driven gyro unit, a solid-propellant motor, four reinforced-plastic wings of very low aspect ratio, trailing-edge control surfaces moved by cordite-gas actuators, and a motor tube to a propelling nozzle surrounded by main and subsidiary wire spools. Guidance electronics are mounted on small strips screwed to the outside of the motor case, and production Vigilants will rely for accessory power either on a thermal cell or on power from a turbo-alternator energized by gas bled from the main motor.

Uncontrolled rounds were fired in the summer of 1957, and guided Vigilants have been fired many times since September 1958. At the invitation of the U.S. Army a presentation was made at Redstone Arsenal earlier this year and orders are now being sought from the armies of Britain, the NATO nations and other countries.

Vigilant: length, 35.46in; wing span, 11in; body diameter, 4.5in; firing weight, approximately 27 lb; effective range, up to about 5,300ft; flight speed, about 350 m.p.h.

XM 60

U.S. Army

High-performance artillery rocket.

DURING the past year persistent reports have spoken of a new artillery rocket designed to succeed the "John" family, and alleged to have a range of up to 65 or 70 miles. Known either by the above designation or as "Missile A," the new weapon will have a solid-propellant motor and is said to be under development by the Missile and Space Vehicle Department of General Electric, whose contract is reported to have been placed in July last.

MISSILES 1959...

AIR TO SURFACE

B.B.10

French Air Force.

Tactical air-to-surface missile.

PRODUCED in small quantities by Sud Aviation, B.B.10 was first seen at the 1957 Paris Salon, when one was displayed beneath the wing of a Vautour. It is essentially a 400-lb h.e. bomb, guided by radio-command, and with a solid motor to extend the range.

B.B.10: length, about 11ft; fin span, about 2ft 8in; launch weight, about 900 lb; flight speed, transonic.

BLUE STEEL

Royal Air Force (Bomber Command).

Supersonic-cruise strategic missile.

FOR at least three years this great weapon system has been the major responsibility of the Weapons Research Division of A. V. Roe and Co. The work is centred at the Division's plant at Woodford, Cheshire, although now that it has reached the flight-test stage it is involving such other establishments as the R.A.E. Aberporth and the range at Woomera. Blue Steel is designed to be carried by the Victor B.2 and Vulcan B.2; it is scheduled to enter service in perhaps two years' time and should extend the useful life of the V-bomber delivery system by several years.

An operational type of Blue Steel has not yet been publicly shown. From the test vehicles and models which have been seen it can be deduced that the missile will manœuvre by twist-and-steer. Evidence suggests that the aerodynamic surfaces comprise: a rear-mounted delta wing with ailerons; a dorsal rudder; a ventral fin (which folds sideways to provide ground clearance when the missile is carried by the Victor); and delta foreplanes which provide control in pitch only. Detail points are that the foreplanes are cropped at the tips to what appears to be a Mach angle suggesting M 2, and that the tips of the wings have anhedral in order to clear the tailpipes of the Victor.

The finely streamlined fuselage has a circular section over most of its length, terminating in a section suited to the de Havilland Double Spectre rocket engine. The latter consists of a fixed-thrust chamber mounted above a fully variable chamber, both being fed by individual turbopumps with H.T.P. and kerosine. This engine, which is described as being fitted in "the initial type of Blue Steel," has a sea-level thrust of 16,000 lb. Chief contractor for guidance is Elliott Bros. (London) Ltd. The all-inertial system is linked with the guidance system of the parent aircraft up to the moment of launching, and each system monitors the other to improve the overall accuracy. Once the missile has been launched it is entirely self-contained and, after an inbuilt programme has controlled the missile during the acceleration to supersonic speed and the subsequent zoom to high altitude (probably at least 90,000ft), the trajectory is controlled in such a way that the flight path will provide the greatest difficulty for defending weapon systems. The missile could approach its target either at low level (and from any direction) or it could dive vertically, the warhead possibly separating like that of the Snark. Blue Steel's structure has been described as incorporating "special precautions to combat aerodynamic heating," suggesting that a speed well over M 2 may be reached during the final dive. Obviously a thermonuclear warhead can be carried.

Following extensive trials with scale models, the final configuration has now been agreed and intensive research with full-scale vehicles is now in hand. Numerous launchings have been made from a Valiant and test vehicles have also been seen beneath at least one Vulcan. According to *Aviation Week* Avro do not yet have a production contract, but this would seem to be merely a matter of time.

Blue Steel: length, about 36ft; wing span, about 13ft 4in; launch weight, probably of the order of 15,000 lb; maximum thrust at altitude, about 19,000 lb; design range, several hundred miles; cruise speed (estimated from foreplane tip angle), M 1.6 (1,060 m.p.h.); operating altitude, well over 60,000 ft.

BULLPUP

U.S. Navy, Air Force and Marine Corps; the missile is ASM-N-7 (U.S.N.) or GAM-83 (U.S.A.F.).

Tactical weapon for launching from carrier-based or tactical aircraft.

ESSENTIALLY the original Bullpup was a 250 lb bomb provided with a rocket motor, fins and canard foreplanes, controlled by radio command, to increase the effectiveness of a strike against heavily defended point targets. Bullpup is cheap, accurate and simple and a complete round is said to cost but $4,000. In production at the Orlando plant of The Martin Company, the latest Bullpups are propelled by a Guardian pre-packaged liquid motor (Reaction Motors Division of Thiokol); previously a solid motor was used. The rear fins are fixed and carry tracking flares, which are watched by the pilot of the launching aircraft and kept in line with the target by imparting left/right and up-down commands by radio link. Bullpup's gyro is driven by a spring.

The basic ASM-N-7 became operational with a squadron of A4Ds aboard U.S.S. *Lexington* on April 25 last, and today several units have Bullpups in both the 6th and 7th Fleets. Last year the U.S. Air Force adopted an advanced development of Bullpup named White Lance. This has now been replaced by the GAM-83B, which will not differ so substantially from the ASM-N-7 ($5m was awarded in September for its continued research and development). In the interim the U.S.A.F. are buying quantities of the standard Navy weapon as the GAM-83A. Meanwhile, the Navy are producing bigger and better Bullpups, one of which will carry a 1,000 lb h.e. warhead and at least one type of nuclear warhead. Originally named Bulldog, this enlarged missile is now spoken of as Super Bullpup.

ASM-N-7/GAM-83A Bullpup: length, 11ft 2in; fin span, 3ft 7in; firing weight, 571 lb; effective range, 10,000 to 15,000ft; flight speed, 1,400 m.p.h.

CORVUS

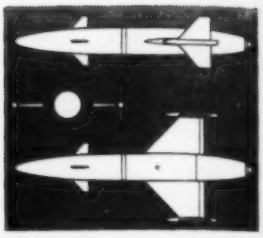
U.S. Navy; the missile is ASM-N-8.

Air-to-surface missile for launching from carrier-based aircraft.

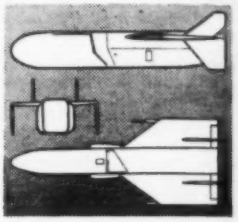
STILL closely cloaked by security, Corvus is a "stand-off" missile which has the greatest supersonic range that can be achieved by a vehicle launched from a carrier-based aeroplane. It is to be carried by such aircraft as the A4D, F4H and A3J to facilitate the penetration of heavily defended ship or shore targets. Last year William M. Holaday said that Corvus would take out "certain enemy equipment," leading to speculation that it may home on to enemy radars. One report says it is specifically intended for use against ship radar. First announcement of it was made in January 1957, when the Navy said that Temco Aircraft Corp. had been given responsibility for the management of the entire weapon system as prime contractor. As the provisional drawing shows, Corvus has a low-mounted swept wing and a cruciform tail.

According to unofficial reports it can be employed in a variety of rôles, the payload comprising either a nuclear or conventional warhead, or any of a variety of countermeasures systems. No clue regarding guidance has been given, beyond the fact that one of the companies involved is W. L. Maxson Corp. Other Corvus sub-contractors are Bulova Research Laboratory, Texas Instrument Co., Horkey-Moore, Douglas Aircraft (Tulsa), Emerson, Talco Engineering, Williamson Co. and the Avion division of ACF.

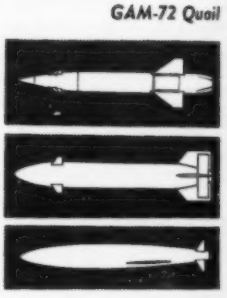
Propulsion is provided by one of the Guardian series of pre-packaged liquid rocket engines by the Reaction Motors Division of Thiokol. During 1958 and the early part of this year, comprehensive static testing took place at the prime contractor's works in Dallas and at the Naval Air Missile Test Center at Point Mugu. The first flight took place at the latter establishment early in July, when a test vehicle—likened to "a great gray goose"—was successfully fired from an A4D.



Robot 304



GAM-72 Quail



ASM-N-7 Bullpup
B.B.10
ASM-N-8 Corvus

CROSSBOW

U.S. Air Force; the missile is Guided Air Missile 67.

Tactical attack and countermeasures vehicle.

DURING the past 12 months no further news has been received of the progress of this cruise-type missile. Under development by the Radioplane Division of Northrop Corp., GAM-67 is an outgrowth of the company's many jet-powered drones and doubtless owes much to the Q-4 family. Like the latter it was originally powered by the Westinghouse J81 (Rolls-Royce Soar), but the eventual powerplant will probably be the J85 or J60. Unofficial reports state that Crossbow cruises at about 500 kt and is designed to home on to enemy electronic installations. Range is reported to be about 200 miles.

GAM-87A

U.S. Air Force (Strategic Air Command); the missile forms part of Weapon System 138A.

Air-launched strategic ballistic missile.

IT was not until late in 1957 that the concept of an ALBM (air-launched ballistic missile) had jelled sufficiently for a specification to be written. Competition for the award of the study contract was intense, at least fourteen companies being reported to have submitted tenders. Early this year the contract was awarded to Douglas Aircraft, who have since taken the paper-work to an advanced stage and marshalled a strong team of possible sub-contractors.

Essentially GAM-87A will extend the striking

MISSILES 1959...

power of SAC bombers more effectively than can the aerodynamic-cruise Hound Dog, owing to its smaller radar cross-section and much higher speed. It appears that the missile will be designed for a range of between 500 and 1,000 miles, describing a ballistic trajectory after a toss-launching at an angle of perhaps 50 deg from the horizontal. Assuming a warhead yield of 4 MT it should be possible to reduce the firing weight to below 20,000 lb. Most of the airframe will be a thin-walled case housing an Aerojet-General solid-propellant motor equipped with jetavators for thrust control. Inertial guidance will be used (Douglas have twice recommended G.E., but the U.S.A.F. have finally decided to use Nortronics Division of Northrop), and the ablative-type nosecone is being studied by G.E.'s Missile and Space Vehicle Department.

Although WS-138A has not so far embraced carrier vehicles apart from the B-52G, B-52H and B-58A, it could obviously include the B-70A Valkyrie; in fact GAM-87A should logically be the B-70's prime armament. Douglas's terms of reference are "to develop specific cost and performance data, to be completed during calendar 1959, to be followed by further cost and effectiveness studies." The system is currently regarded as one of the most important U.S.A.F. projects, but it was "re-appraised" last month to determine whether or not it can be properly financed during the next Fiscal Year.

It is worth noting that other ALBMs, built for the earlier Weapon System 199A, have reached the hardware stage. GAM-87's unsuccessful competitor by The Martin Company, named Bold Orion, has been launched from a B-47 on several occasions, and Lockheed have built a number of ALBMs for Convair, one of which was fired at the end of September from a B-58.

HOUND DOG

U.S. Air Force (Strategic Air Command); the missile is Guided Air Missile 77 and it forms part of Weapon System 131B.

Supersonic-cruise, winged, air-breathing vehicle for launching from a strategic bomber to accomplish delivery of a nuclear warhead.

FOLLOWING the cancellation of Rascal, Hound Dog is the only means by which a bomber of SAC can be reasonably certain of placing a nuclear warhead on a heavily defended strategic target. Teamed with the Boeing B-52G and B-52H missile-platform bombers, it promises to extend the useful life of these great aircraft by several years, maintaining their effectiveness until the B-70 becomes operational in 1964. After an intense competition GAM-77 was awarded to the Missile Division of North American Aviation in August 1957.

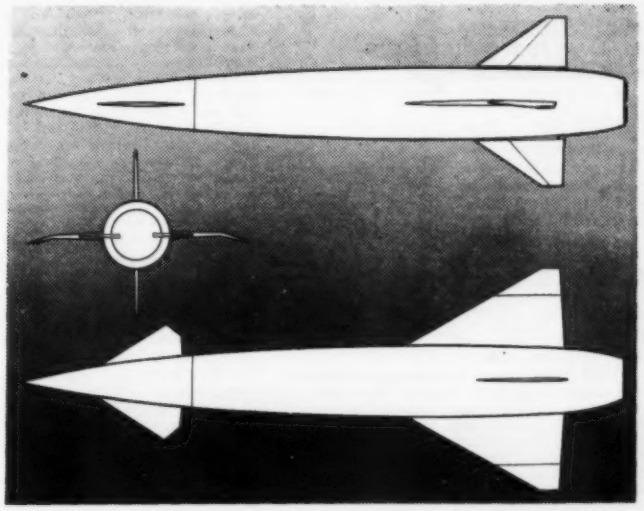
Hound Dog is a member of the great canard family which started with X-10 and now embraces the B-70. Manœuvring by twist-and-steer is effected by a rudder, ailerons and foreplane, controlled by an all-inertial system produced by the prime contractor's Autonetics Division. Into this system is fed positional information from the parent aircraft up to the point of release; it thereafter controls the flight of the Hound Dog up to a height of well over 60,000ft and finally causes it to dive on to its target, while the parent aircraft returns to its base. The largest GAM-77 warhead may have a yield as high as 20 MT, and it is likely that it is designed to separate during the dive on to the target.

Propulsion is provided by a Pratt & Whitney J52 turbojet, rated at 7,500 lb thrust, contained in an underslung pod at the rear of the missile. In order to achieve optimum powerplant performance throughout each mission the intake is provided with a fixed multiple-shock centrebody and the nozzle also has a centrebody providing a convergent/divergent profile which apparently can be modified in flight. Tankage for JP-6 fuel is contained in the fuselage.

N.A.A.'s Missile Division were awarded an initial production contract in November 1958. Flight testing is being conducted with a B-52 operating over the Atlantic Missile Range from Eglin A.F.B. Like the later operational B-52s this aircraft is equipped to carry two Hound Dogs on underwing pylons which contain monitoring and launching equipment. On April 23 the first powered XGAM-77 test vehicle was flown on a limited range test, and several other missiles have since been launched successfully.

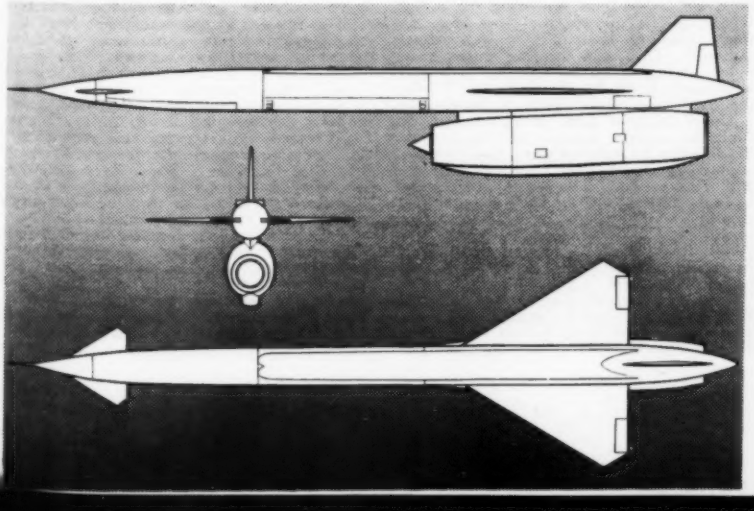
Hound Dog is so self-contained that little is needed to complete the system, beyond lifting and transportation trailers and work-stands (Cleman Engineering) and engine-test stands, control cabinets and missile kits (Space Corp.). Initial operational capability is scheduled before next June 30. Bases which are preparing to receive both Hound Dog and the associated Quail decoy are: Altus, Okla; Blytheville, Ark; Dow, Me; Eglin, Fla; Griffis, N.Y.; Loring, Me; Minto, N.D.; Ramey, Puerto Rico; Seymour Johnson, N.C.; Wright-Patterson, Ohio; and Wurtsmith, Mich. Target-trajectory data will be processed at a new centre established at SAC Headquarters at Offutt A.F.B. and will be fed to Hound Dogs automatically.

GAM-77 Hound Dog: length, 42ft; wing span, 12ft; launch weight, about 10,000 lb; thrust (sea level), 7,500 lb; cruise speed (estimated from tip angles of wing and foreplane), M 2 (1,320 m.p.h.).



Blue Steel (test vehicle)

Below, Hound Dog



QUAIL

U.S. Air Force (Strategic Air Command); the vehicle portion of this system is Guided Air Missile 72.

Air-launched countermeasures vehicle.

IN order that the heavy bombers of Strategic Air Command may protect themselves by creating a favourable electronic environment, McDonnell Aircraft were asked to develop the GAM-72, named Quail (originally Green Quail). It is a miniature aeroplane packed with countermeasures which is released by the bomber before the latter is identified by enemy target-defence radars. Details of the countermeasures systems which Quail carries are classified, but it seems logical to suppose that the vehicle can fly at the same height and speed as a B-47 or B-52 and can return an identical radar picture, while the bomber attempts to make itself electronically invisible.

In order to minimize the radar cross-section of Quail, and thus permit the countermeasure to build on a relatively clean sheet of paper, the airframe is not only exceedingly small, but is fabricated almost entirely in reinforced plastics. Propulsion is provided by a General Electric J85-7 turbojet rated at 2,450 lb sea-level thrust.

Following extensive captive tests at St. Louis and glide testing at Holloman A.F.B., a series of recoverable test vehicles have been undergoing flight testing at Holloman for at least two years. Total contracts for Quail amount to more than $45m.

GAM-72 Quail: length, 13ft 3in; wing span (spread), about 5ft 6in; launch weight, 1,100 lb; thrust (sea level), 2,460 lb; range, 200 miles at tropopause; flight speed, up to M 0.9 (600 m.p.h.).

RASCAL

U.S. Air Force (Strategic Air Command); the missile is Guided Air Missile 63.

Rocket-propelled, winged missile for attacking strategic targets.

DESCRIBED and illustrated in our 1958 Missiles issue (December 5), Rascal was a supersonic-cruise weapon which, together with its triple-barrel rocket engine, was produced by Bell Aircraft. As a concept, however, Rascal has been overtaken by later developments, and it was cancelled on September 9, 1958.

GAM-63 Rascal: length, 31ft 11.5in; wing span, 16ft 8.5in; launch weight, about 13,500 lb; design range, 75 miles; flight speed, M 1.5 (1,000 m.p.h.).

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ROBOT 304

Royal Swedish Air Force.

Transonic tactical missile for launching from high-speed strike aircraft.

EXISTENCE of Robot 304 was announced in 1957, and little additional information has since become available. Propulsion is provided by a two-stage solid-propellant motor and the weapon's flight is controlled by the foreplanes.

Project work on Robot 304 started in March 1950. The first test vehicle was launched on February 11, 1955, and the Robotbyran state that 304 is now ready for service. It is operationally deployed with Attack Wings F6, 7, 14 and 17, all of which are equipped with the A-32A Lansen.

Robot 304: length, 14ft 9in; wing span (including tracking flares), 6ft 8in; body diameter, 19.4in; firing weight, about 1,200 lb; effective range, several miles; flight speed, transonic.

WAGTAIL

U.S. Air Force.

Tactical missile for launching from supersonic aircraft.

DURING the past year no further news has been received of the progress of this unusual missile, the prime contractor for which is Minneapolis-Honeywell. Provided with an inertial guidance system, said to be the work of the prime contractor, Wagtail is intended to approach a target at low altitude after launching at around M 2.

ANTI-SUBMARINE

ASROC

U.S. Navy.

Anti-submarine rocket.

UNDER development by Minneapolis-Honeywell under an R. & D. contract from BuOrd, Asroc is a weapon system intended to replace Rat, and it outperforms the earlier system substantially. Range through the air is expected to be at least 10 miles, and the terminal homing is accomplished acoustically. Like Rat, Asroc was designed by the NOTS at China Lake, and is intended for installation aboard surface ships only.

ASTOR

U.S. Navy.

Submarine-to-submarine missile system.

WITH a name derived from its function—anti-submarine torpedo ordnance rocket—Astor will consist essentially of a nuclear warhead (kiloton range) with propulsion and guidance system suitable for a flight through the water, followed by a ballistic trajectory through the air and terminal homing on to a submerged target. One report mentions wire guidance. Prime contractor is Westinghouse.

MALAFON

French Navy.

ASW weapon system.

DEVELOPED and manufactured by Latécoère, Malafon will form the main armament of *La Galissonière*, a fast ASW ship now under construction. The missile is launched by solid boost motors, cruises on the thrust of an integral ramjet and is guided by radio signals to hit surfaced or submerged submarines.

RAT

U.S. Navy.

Rocket-assisted Torpedo.

CONCEIVED at the Naval Ordnance Test Station at China Lake, Cal, Rat is essentially an assemblage of underwater search and detection equipment, a fire-control system, a launcher and a missile; and the latter comprises a standard homing torpedo attached to a jettisonable airframe incorporating stabilizing surfaces and a solid-propellant rocket. When about to enter production the programme was cancelled in January of this year, owing to the evolution of superior ASW systems.

SUBROC

U.S. Navy.

ASW missile system for launching from above or below the surface.

THE Subroc system is designed to "detect a submarine at long range, compute its course and speed, and fire the missile. The missile is propelled through the air by a rocket which drops away and the warhead continues on to the target. The weapon can destroy enemy targets in an area of many square miles around the launching submarine." The missile itself is clearly torpedo-like in character, and when it is launched it probably has hydrodynamic and aerodynamic surfaces. One unofficial source claims that its range through the air will be 25 to 50 miles, the flight speed being supersonic. The warhead will be either conventional or nuclear.

The research and development contract has been awarded to Goodyear Aircraft. Worth $65m, this contract covers the complete weapon system, including tooling and production methods. Basic development has been handled by the Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland. Principal sub-contractors to Goodyear are Librascope and Kearfott.

SURFACE TO AIR

ADVANCED TERRIER

U.S. Navy and Marine Corps.

High-performance anti-aircraft missile for use from large surface ships and beachhead launchers.

As a natural outgrowth of Terrier (page 529) Advanced Terrier is an entirely new missile which can be integrated with the existing Terrier system. It is now in production at the Naval Industrial Reserve Ordnance Plant, operated by Convair at Pomona, Cal.

All that the Department of Defense are prepared to say is that Advanced Terrier incorporates improved guidance features and provides "substantial improvements in coverage." It is fired from a twin launcher by a tandem boost motor with a thrust greater than that fitted to Terrier. After boost burn-out the solid sustainer is ignited and the control system becomes operative.

Compared with its predecessor, the aerodynamics of the missile have been completely changed. The cruciform of moving wings has been moved to the tail and the operating ring now encircles the motor nozzle. Flight stability is provided by four wings of exceedingly low aspect ratio which are bolted along the sides of the body, the trailing edges of these surfaces reaching to the leading edges of the cruciform controls. The manner in which the guidance system has been improved may not be divulged, but it may well be that semi-active terminal homing has been incorporated. Guidance and control systems were designed by Convair under the technical direction of the Applied Physics Laboratory of Johns Hopkins University, and are manufactured by Convair at Pomona. Responsibility for propulsion is the Allegany Ballistics Laboratory. The warhead was designed by the Naval Ordnance Laboratory at White Oak and its fuze was designed by the Naval Ordnance Laboratory, Corona.

Under present shipbuilding programmes the Advanced Terrier will become "a major element in the Navy's missile arsenal." Late this year the first Advanced Terrier ship will be commissioned; she will be U.S.S. *Dewey*, a guided-missile frigate. She will be followed by the nuclear-powered carrier *Enterprise*, two conventional carriers, the nuclear-powered cruiser *Long Beach*, three conventional cruisers, the nuclear-powered frigate *Bainbridge*, and 18 conventional frigates additional to *Dewey*. Moreover Advanced Terrier will be employed by the U.S. Marine Corps in an *ad hoc* system including portable radars, launchers and loaders. A production contract for $31.4m was announced last January 19.

Advanced Terrier: length, about 14ft 10in (29ft 6in with boost motor); wing span, about 20in (fin span, 3ft 5in); firing weight, about 5,000 lb (1,500 lb without boost motor); maximum range, 20 miles; burnout speed, about M 3.

BLOODHOUND

Royal Air Force (Fighter Command) and Royal Swedish Air Force.

Semi-active homing weapon system for area defence from fixed bases.

A DETAILED description of the complete Bloodhound weapon system, together with a cutaway drawing of the missile, appeared in our issue of October 23. As the standard surface-to-air guided weapon system of the R.A.F. Bloodhound is perhaps the most important single piece of equipment in our defence inventory. It is also the first surface-to-air missile developed in this country to become operational; and it has the distinction of being the first British missile to win an export order.

Under the code name of Red Duster, the complete weapon system has been under development for some ten years, the prime contract being placed with Bristol Aircraft and with Ferranti Ltd. The former concentrated upon the airframe and the latter upon the electronic portions of the system, and further major contributions have been made by Bristol Aero-Engines (now Bristol Siddeley) in the sphere of propulsion and by M.L. Aviation for ground-support equipment.

Production airframes are manufactured at Bristol Aircraft's plant in Cardiff. Deliveries are normally made by road to user Air Defence Missile Squadrons of R.A.F. Fighter Command. Upon receipt the missiles are assembled and checked out before being placed on launchers. The latter may be mounted on a wheeled chassis together with other portions of the weapon system, but for the defence of the United Kingdom the Bloodhound is operated from airfield bases and is integrated with the existing British control and reporting network.

All missiles on launchers are fully armed with warhead and boost motors and their kerosine tankage is kept continuously topped-up. A normal Fire Unit comprises 16 launchers, together with tactical-control and target illuminating radars, a launch-control post and a workshop.

Should an incoming target be sighted by the early-warning radar system its progress would be plotted automatically and the EW television picture transmitted by microwave relay to the operators in the main control room. As was outlined in our issue of November 7 last, it is the duty of a target selection officer at this centre to decide when a particular target can be engaged by the Bloodhound Fire Unit under his control, and then to feed the relevant data from automatic storage to the Sting-Ray (produced by B.T.H.) target-illuminating radar of the Fire Unit chosen. Although precise details remain classified it appears that each Fire Unit is divided into two groups each of eight launchers served by their own Sting-Ray. Thus, from one to eight missiles could be fired virtually simultaneously and homed on to a given target, while the other eight rounds could be concurrently homed on to a different target.

As soon as the target has been acquired by the big tactical-control radar the latter starts to provide a volumetric (3-D) picture of the overall situation, and also turns the dish of an associated Sting-Ray so that the latter may lock-on at the earliest possible moment. When the Sting-Ray has locked-on, the target remains "illuminated" by a powerful pencil beam, the reflection from which provides a source of energy upon which the receiver dish aerial in the nose of the Bloodhound can home. Movement of the Sting-Ray scanner produces a corresponding slewing movement of its associated launchers, so that each missile starts its flight

pointing in the correct direction; at the same time the receiver dish in each Bloodhound is locked-on to its target before the missile leaves the launcher. The final refinement is that the transmission from each Sting-Ray is tuned or coded to catch the receiver circuit in one particular Bloodhound. This prevents confusion between the various Sting-Rays and missiles in flight and also provides increased resistance to countermeasures.

At the end of the boost phase, the four boost motors petal off to the rear and leave the Bloodhound to cruise a high supersonic speed on the thrust of the twin Thor ramjets mounted above and below the body. Manœuvres are accomplished by twist-and-steer, the tailplane being fixed but the wings being hydraulically powered to move differentially or together to provide rolling or pitching moments. Since semi-active homing guidance is employed, the accuracy of the proportional-navigation interception trajectory increases as the target is neared, and the warhead is finally detonated by a proximity fuse or by impact.

Bloodhound Mk 1 is now deployed with Fighter Command as an integral part of the U.K. defensive system. Late last year the Royal Swedish Air Board signed a contract for an evaluation quantity.

It has been announced that the complete weapon system is to be progressively extended in performance by a series of steps, each of which will remove an existing limitation. By such obvious means as the employment of more powerful target-illuminating radars, higher-thrust boost motors, later ramjets and increased internal tankage, it should be possible substantially to increase the range and lethality of the system without introducing any major change requiring re-training of personnel. Bloodhound Mk 2 has been stated to have greatly improved lethality against targets down to ground level.

Bloodhound Mk 1: length, 22ft 2.4in (25ft 3in with boost assembly); wing span, 9ft 4.5in; body diameter, 21.5in; firing weight, probably about 2,500 lb (about 4,500 lb with boosts); maximum range, "several score" miles; flight speed, at least M 2.

BOMARC

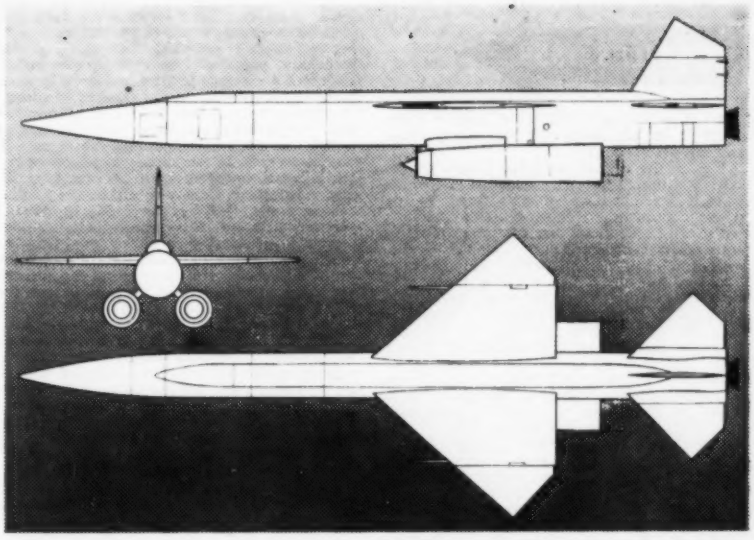
U.S. Air Force and Royal Canadian Air Force. Terminal-homing area-defence missile for integration with SAGE network.

OFFICIALLY described as an area-defence weapon—in contrast to the Nike system—Bomarc is virtually a high-performance intercepter from which the pilot has been deleted. Tied in with the SAGE electronic network it can be fired automatically from a remote base and vectored into the vicinity of the target, whereupon its own seeker head takes over and steers the missile on a collision course. It has a greater range than any other anti-aircraft weapon, and each Bomarc base can guard more than 100,000 sq miles of territory.

Authorization of the programme by the U.S.A.F. took place in 1949. At that time the two partners responsible were Boeing and the Michigan Aeronautical Research Center, their names leading to the "Bo-MARC." After many hundreds of test firings a complete weapon system was evolved, and the first production IM-99A missile was rolled out from Boeing's Seattle plant on December 30, 1957.

Like the British Bloodhound, Bomarc manœuvres by twist-and-steer, its movable surfaces comprising the top of the vertical tail, the tips of the wings, and all but the innermost portions of the horizontal tail. Much of the airframe is built up from magnesium sheet and some 30ft of the body is integral tankage for kerosine fuel. The IM-99A takes off vertically under the thrust of an Aerojet General LR59-AG-13 liquid propellant motor, the chamber of which can be gimballed to provide initial stabilization. Acceleration during the forward climb is such that the cruise ramjets can be lit before the missile levels out at altitude. The ramjets are by Marquardt, and the current production model is the RJ43-MA-3. After mid-course guidance under SAGE command and terminal homing by a fully-active system by the Air Arm Division of Westinghouse, the conventional or nuclear warhead is detonated by a proximity fuze. Notes on the weapon system as a whole follow after the description of the more advanced IM-99B.

The latter, otherwise known as the Advanced Bomarc or Superbomarc, is externally very similar to the IM-99A but has vastly improved performance. It differs in three chief respects:



IM-99B Bomarc (same scale as missiles on pp. 526-7)

the boost motor is a high-impulse solid unit by Thiokol (the case and nozzle are not jettisoned); cruise propulsion is provided by the improved RJ43-MA-7 engine, which has already flown at M 3.95 at 100,000ft; and the terminal-homing target seeker is of a more advanced (coherent-pulse Doppler?) type to give the missile "mission capability from sea level to extremely high altitudes." In fact Bomarc B can home from 70,000ft on to a target flying at 50ft.

Some dozens of IM-99A missiles have been fired from Cape Canaveral and Eglin A.F.B. during the past 12 months. Highlights of these tests were the successful interception of X-10 drones flying at over 1,000 m.p.h. and the launching of missiles under remote command from the SAGE Center at Kingston, N.Y., some 1,500 miles distant.

Operationally Bomarc is being deployed from 12 or 14 bases throughout the U.S.A. and additional bases will be integrated in Eastern Canada. The R.C.A.F. decided to buy Bomarc at the beginning of the year, following cancellation of the Arrow intercepter. The R.C.A.F. IM-99Bs will be integrated with the American Bomarcs as part of NORAD. Canadair Ltd. are making Bomarc wings and ailerons under sub-contract to Boeing and the first set was shipped last May, ten weeks after the contract was placed. Additionally 150 Canadair engineers have been assigned to Boeing for between six months and a year, to fill responsible posts in the evolution of the IM-99B development programme.

Bomarc bases so far announced are Suffolk, Long Island, N.Y.; McGuire, N.J.; Dow, Bangor, Maine; Otis, Falmouth, Mass; and (for future construction) near Albany, Oregon, Everett, Washington; Sault Ste. Marie, Michigan; Winooski, Vermont; Hampton, Virginia; Madison, Wisconsin; Lompoc and Sacramento, Cal; Niagara Falls, N.Y.; and Duluth, Minn.

Each base will normally house one flight of 28 missiles, except for Suffolk and McGuire which will each house two such flights. A complete base has 272 men. The 28 missiles will be individually housed in air-conditioned concrete and steel shelters, linked by land-line to a SAGE direction centre from 50 to 300 miles distant. Each shelter is a windowless concrete and steel building 60ft long, 20ft wide and almost 12ft high. Pressing a button in the SAGE centre will cause the two 6-ton halves of the roof to roll apart, while a battery of hydraulic accumulators bring the missile to its vertical position ready for firing. The shelters are unmanned and are visited only occasionally for routine checks. The only "active" areas in a Bomarc base are the assembly and maintenance shops and their support facilities. Total reaction time of the system is less than two minutes, and is expected eventually to be brought down to 30 sec. Moreover, owing to its automatic character and the terminal-homing ability of each missile, the system can in theory fire 30 Bomarcs per second and control 200 of them at the same time.

Basic research and development for the Bomarc B cost $300m, roughly half of which has now been spent. The first of these advanced missiles was fired on May 27 and the second in July, and its development is proving most satisfactory. In recent months the complete system has been fighting a major political battle with the Nike Hercules and Zeus, and it appears to have emerged the victor. Funding for FY60 amounts to $364.5m, and the total cost of installing Bomarcs to cover North America is estimated at about $6b (excluding the SAGE system). Bomarc A is already semi-operational at Suffolk and McGuire; Bomarc B is to enter service in December next year, and the integration of all currently programmed bases with the SAGE network is scheduled to be completed late in 1961.

IM-99B Bomarc: length, about 49ft (body, 47ft 4in); wing span, 18ft 2in; body diameter, 34.6in; launch weight, approximately 15,000 lb; maximum range 440 nautical miles (506 miles); flight speed, about M 3.8 at heights over 68,000ft.

HAWK

U.S. Army and Marine Corps (and, shortly, the armies of Western Germany, Italy, Belgium, France and Holland); the missile is M3.

Semi-active homing missile for employment from mobile installations against low-flying aircraft.

THE name Hawk is formed from the initial letters of "Homing All-the-Way Killer." The weapon system was planned in 1954 to close the last loophole in the defence of the U.S.A. against manned aircraft, and it has been designed specifically for the protection of Army and Marine Corps units against aircraft flying at altitudes down to sea level (the operational altitude limits are given in the data at the end of this account). In the event, the U.S. Army have elected not to buy Hawk for deployment from fixed bases. Instead, all portions of the weapon system have been made transportable by front-line aircraft, including helicopters down to the size of the H-34 (S-58). When properly emplaced, the system can maintain a rate of fire appreciably higher than can the Nike system (which in this respect is limited by its command guidance).

Prime contractor for the Hawk system is Raytheon, although Northrop manufacture the airframe and share with Food Machinery the work of providing most of the ground equipment. The missile itself is quite small and is unusual in not having a separate boost motor. Aerojet-General manufacture the solid-propellant motor to a design originally evolved by Thiokol. The first portion of the charge burns with high thrust to act as a booster, and the sustainer exhausts from a smaller central nozzle. The motor casing, forming the missile

MISSILES 1959...

body, is deep-drawn from steel, and to it are attached the cruciform of highly swept wings and the nose radome.

Key to the operational effectiveness of the system is the advanced guidance radar, which is both developed and manufactured by the prime contractor. Details remain classified, but it can be deduced that the target-illuminating set is a coherent-pulse Doppler device, with two dish aerials, which automatically tracks a moving target while ignoring unwanted reflections from stationary objects on the ground. Clarity of resolution is outstanding, and according to unofficial reports the radar can pick out an individual target from a close formation of aircraft at a range of 22 miles. The complete set is mounted on a single pair of soft-sprung wheels for transport, but is raised on four jacks to provide a rigid base once a firing location has been chosen.

The transmission is coded to control one or more particular missiles, each of which homes on to the return radiation reflected from its own target. The flight of the missile is controlled by hydraulically powered surfaces mounted at the trailing edges of the four wings. The warhead is officially described as being a high-explosive head of advanced design (several types of warhead can be fitted), and is detonated by a proximity fuze or by impact. In order to maintain the required rate of fire a triple launcher is employed, and this is loaded by a self-propelled tracked loader which carries three rounds at a time.

Under the original plan, the U.S. Army would have employed Hawk from fixed emplacements, each battery of 36 missiles requiring a 40-acre site and having 12 triple launchers protected beneath hemispherical shelters. A number of sites had actually been selected, particularly in the areas of Washington, Baltimore and New York City. Nevertheless, procurement of Hawk for use in the U.S.A. has been curtailed, and the Army will now have only 15 battalions, of which 13 are scheduled to be operational by next June 30. Hawk battalions deployed within the U.S.A. will be controlled by the MSQ-18 Missile Monitor electronic network. In battalions deployed to overseas theatres by the Army or Marine Corps no external control would be exercised, each formation being capable of operating independently. Appropriations for FY59 and FY60 were $213m and $127.7m. From the earlier vote Raytheon were last June awarded a $161m letter contract, of which $61m were for missiles, $84m were for ground-support equipment and $16m covered "engineering services." Until early this year development-production of complete systems was handled by the Army at White Sands but volume assembly is now to be centred at the Red River arsenal at Texarkana, Texas.

At the Summit Conference in 1957 President Eisenhower promised assistance to NATO nations who wished to build advanced weapons. Arising from this promise has stemmed a plan for the widespread deployment of Hawk systems manufactured jointly by five NATO nations. Agreement has at last been reached for the establishment of 22 battalions (Western Germany 9, Italy 4, and Belgium, France and Holland 3 each). Unofficial estimates place the cost of the programme at $440m, of which some $40m will be contributed by America under MDWP; funding will extend over the next five years, and initial deliveries are due to begin by June 1961. Production is to be managed by an *ad hoc* company, registered in France as the Société European de Téléguidage. Under it has been marshalled a large number of firms, co-ordinated technically by the Compagnie Francais Thomson-Houston, and including such famous names as Telefunken, Philips, Finnmeccanica and Ateliers de Constructions Electrique de Charleroi.

XM3 Hawk: length, 16ft 9in; wing span, 49in; body diameter, 14in; firing weight, 1,275 lb; maximum range, 22 miles, against targets flying at from under 100 to over 38,000ft; flight speed, over M 2.

MARUCA

French Navy.

Command-guidance anti-aircraft missile.

FIRST illustrated in our 1957 Missiles issue, Maruca has been produced in some quantity at the Ruelle Naval Arsenal. In some respects resembling a Seaslug, but with much lower performance, it has a length of 15ft and is being employed as a general-purpose vehicle for proving components of later systems and training personnel.

MASALCA

French Navy.

Ship-to-air missile.

ANOTHER member of the Latécoère ship-to-air family, Masalca is a Talos-type weapon, with an integral ramjet body boosted by a tandem solid motor. The missile has large moving delta wings arranged as a cruciform in line with small fixed rear fins. The intake centre-body contains a receiver aerial which, at the end of the beam-riding stage, locks-on to its target (presumably with the aid of a semi-active system). Launch weight with boost is of the order of 6,000 lb, and the design range is approximately 60 miles.

MASURCA

French Navy.

Semi-active homing ship-to-air missile.

NOW in an advanced stage of flight development, Masurca is intended to be the definitive anti-aircraft missile for use on the larger ships of the French Navy. Produced by the Ruelle Arsenal, the missile itself has cruciforms of rear wings and delta moving foreplanes indexed in line. It is launched by a tandem boost motor and has a solid-propellant sustainer. In the test vehicles all four of the wings carry tracking flares, but the operational missile is said to be a beam rider with terminal homing.

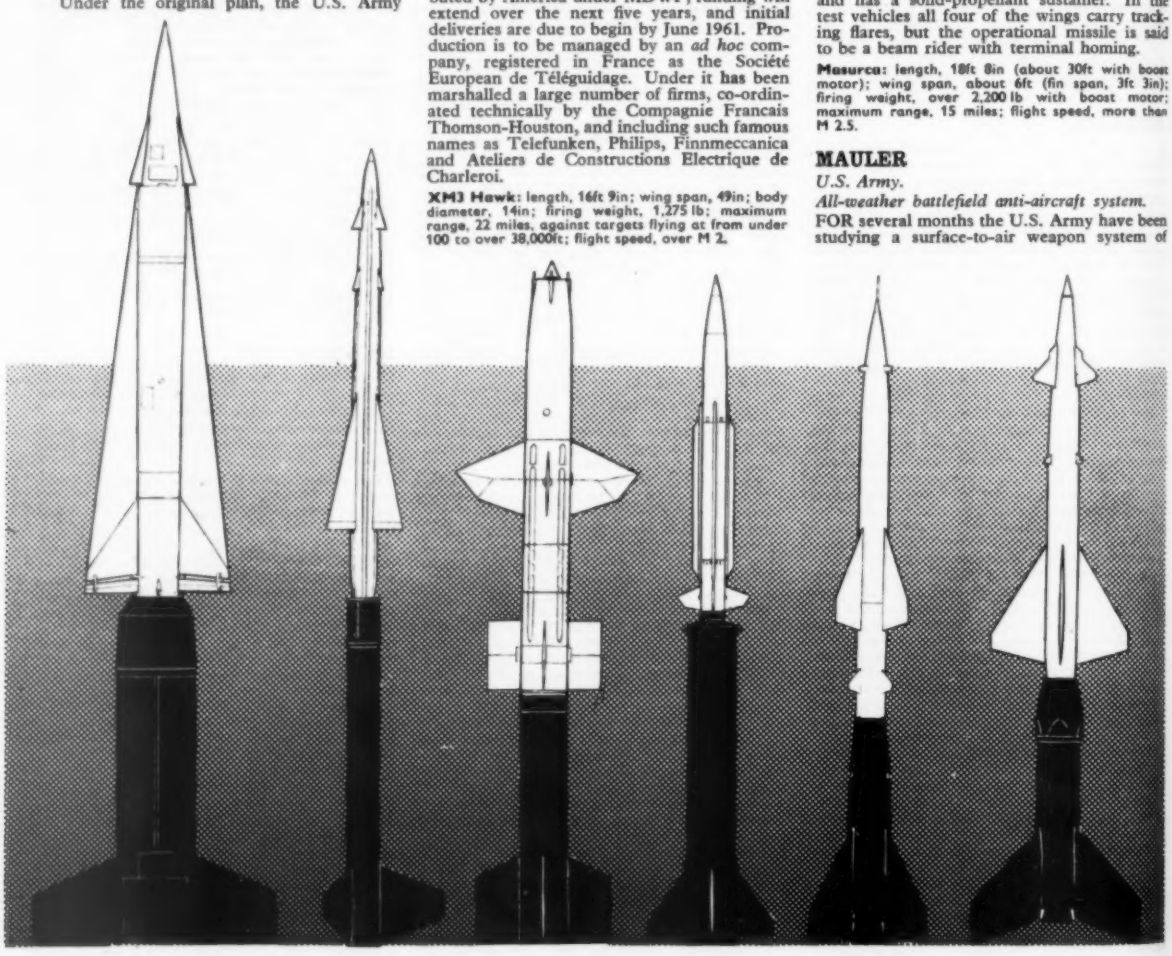
Masurca: length, 18ft 8in (about 30ft with boost motor); wing span, about 6ft (fin span, 3ft 3in); firing weight, over 2,200 lb with boost motor; maximum range, 15 miles; flight speed, more than M 2.5.

MAULER

U.S. Army.

All-weather battlefield anti-aircraft system.

FOR several months the U.S. Army have been studying a surface-to-air weapon system of



Nike-Hercules | Nike-Ajax | Talos | Advanced Terrier | Soviet A.A. missile | R.422-B1

unusual character, under the project name of Mauler. Features unofficially ascribed to it are extreme mobility (one report says the entire system is carried on one powered chassis), the ability to operate in any kind of battle situation or terrain, and true all-weather capability.

MTG-CI-58

Italian Air Force.

Beam-riding anti-aircraft weapon system for mobile deployment.

DURING the past three years Contraves Italiana in Rome have been in limited production with the Contraves/Oerlikon RSD-58 and RSC-57; the Italian versions are the MTG-CI-58 and MTG-CI-57.

NIKE AJAX

U.S. Army (throughout the U.S. and in many overseas theatres), and Armies or Air Forces of several other countries, including Western Germany and France; the missile is SAM-A-7.

Command-guidance, fixed-base missile system.

FULL details of this widespread anti-aircraft system were contained in our previous three Missiles issues—especially the first such issue on December 7, 1956.

Radars track the target and the missile, a computer compares the two trajectories and at the appropriate moment injects a variation into the coding of the command signal to detonate the warheads (there are three warheads disposed longitudinally along the missile body, with a total weight of 313 lb). Prime contractor for Ajax is Western Electric. Responsibility for guidance is shared with Bell Telephone Laboratories, and airframes were made at the Army Ordance Missile Plant at Charlotte, N.C., managed by Douglas Aircraft. Almost 20,000 rounds were delivered when production ceased last year. Most Ajax emplacements have now been converted to take the much more effective Hercules.

SAM-A-7 Nike Ajax: length, 21ft (34ft 10in or 35ft 5in with boost motor); wing span, 63in; body diameter, 12in; firing weight, 1,100 lb (2,300 lb with boost motor); maximum range, 25 miles; flight speed, M 2.5.

NIKE HERCULES

U.S. Army (home and overseas deployment); the missile is SAM-A-25.

Command-guidance missile for integration into the existing Nike system.

WHEN the Nike system was planned for the defence of the U.S.A. it was deliberately conceived as a flexible system, the performance of which could be progressively improved by the step-by-step introduction of components of higher performance. The largest single improvement so far has been the substitution of the Hercules missile for the much earlier Ajax. Compared with its predecessor Nike Hercules is far more lethal (one official report says it is "fifteen times as effective"), although it still has to fit into the electronic-command environment of the basic system.

Hercules is launched by a four-barrel boost motor, and thereafter flies on the thrust of a high-impulse solid sustainer by Thiokol. Guidance remains the basic Nike radar-command system, although the electronic power is substantially increased to match the much greater range of the missile. A variety of conventional and atomic warheads may be carried. Prime contractor is Western Electric, and airframes are made at the Charlotte Ordnance Missile Plant operated by Douglas Aircraft.

Some 300 Hercules have now been fired against targets flying at altitudes between 5,000 and 100,000ft. A year ago a Hercules fired from White Sands destroyed a Q-5 drone flying at over 1,500 m.p.h. at more than 12 miles' altitude. During the past year the fight for money in competition with the Air Force's Bomarc has been intensified. As a result the programme of equipping all the Army's anti-aircraft missile battalions with Hercules has fallen somewhat behind schedule, but by the end of the current Fiscal Year (FY60, ending next June 30) Hercules will equip 50 batteries, leaving two still armed with Ajax. Last year batteries were deployed in Formosa and Western Germany, and under FY59 50 batteries were voted at 25 locations in the U.S.A. and eight in Hawaii. In May the Senate Armed Services Committee drastically cut the Hercules appropriation; FY60 makes available $98.4m—about enough to maintain the effectiveness of the Nike system for two months—and $100m was transferred from Hercules to other Army weapons.

SAM-A-25 Nike Hercules: length, 26ft 9in (39ft 9in with boost motor); wing span, 90in; body diameter, 31.5in; firing weight, approximately 5,000 lb (10,000 lb with boost motor); maximum range, over 75 miles at heights in excess of 100,000ft; flight speed, M 3.35.

NIKE ZEUS

U.S. Army.

High-performance surface-to-air missile system.

ACCORDING to the U.S. Department of Defense "Nike Zeus is being developed to provide a defense of the continental U.S. against all forms of the air threat, with special emphasis on the ICBM threat. It is the only active system in development to meet the ICBM threat." Zeus should also have anti-satellite capability. It has several times been emphasized that no other system with comparable performance could be made available until the late 1960s.

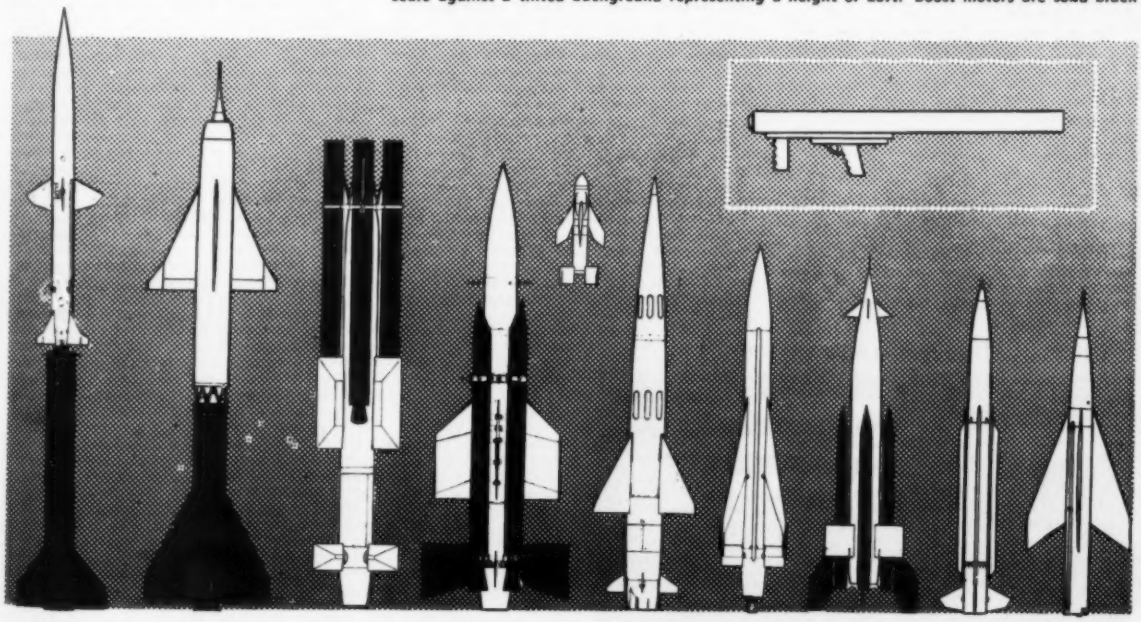
To the maximum possible extent Nike Zeus is an extension of the present Nike system, and it is being developed by the same team of Western Electric (prime), Douglas Aircraft and Bell Telephone Laboratories which has been responsible for its predecessors during the past 13 years. The technological problems involved in developing any such system are immense. Not only does the missile have to have enormous acceleration and hypersonic speed through the atmosphere, but the entire electronic environment necessary is one of immense power, range and reliability. Moreover, the missiles must be tied in with the BMEWS (Ballistic Missile Early-Warning System) and the latter, or the second-stage tracking radars, must be capable of locking-on unfailingly to an incoming nosecone, while rejecting all spurious targets and decoys. The present SAGE system has too short an electronic range for anti-missile purposes, and very heavy expenditure will be required to remove this limitation.

Last July Sperry revealed that for almost two years they had been working against a $4m research and development contract with Bell Telephone Laboratories on target-tracking radars of extreme power suitable for the Nike Zeus system. Also relevant is the announcement made in September that R.C.A., at Moorestown N.J., hold a $4.43m contract for u.h.f. precision-tracking radar. Further notes on Zeus radar were published in our 1958 review (December 5, p. 893).

Few clues have been given to the configuration of the Zeus missile itself. It has been suggested, however, that it will generally resemble a larger Hercules, with a wing having even more acute taper. Firing weight will almost certainly exceed 10,000 lb for the basic missile, and the tandem booster accordingly has a thrust reported to be 450,000 lb. Several of these giant boosters have now been fired by Thiokol at Huntsville. Olin Mathieson are investigating a propellant of higher specific impulse. The sustainer, by the Grand Central Rocket Co., has been fired. Zeus will, of course, carry a nuclear warhead.

Initial test firings are being handled at White Sands, N.M., and this range is being extended northwards for this purpose. The first missile was launched in August, and it achieved spectacular disintegration. The

Apart from Red-Eye (twice normal size, in the white box) these missiles are drawn to a common scale against a tinted background representing a height of 25ft. Boost motors are solid black



Terrier *Sud 4400* *Seaslug* *Thunderbird 1 Seacat (above)* *RSD-58* *Hawk* *Parca* *Tartar* *Nord 5301*

MISSILES 1959...

second test-firing took place on October 14, and although it fell short of its planned range it "yielded the desired technical data." An additional launch emplacement is being constructed at Kwajalein Atoll in the Pacific where missiles will eventually be fired to intercept nosecones from ICBMs fired from Vandenberg, or from IRBMs launched from a new pad being built at Johnston Island.

At the present time the chief barrier to widespread adoption of the Zeus system is financial. Brig-Gen. A. W. Betts recently said that "the Army's capability of defending America against an ICBM is virtually certain," but he questioned whether it was worth "the tremendous investment necessary." As an indication of the cost of about 40 sites, William M. Holaday, special assistant secretary of defense for guided missiles, considers that the research and development necessary would cost not less than $8,000,000,000. As things stand at the moment no other service is trying to oust the Army from the anti-missile picture, but the cost of implementing an operational programme is so immense that a dossier is almost certain to be sent to the White House. It is pertinent to note that late in September a special briefing was arranged for Dr. George Kistiakowsky, the President's science advisor.

Nike Zeus: length, about 30ft (about 50ft with boost motor); firing weight, about double the weight of Hercules; maximum range, about 200 miles; flight speed, M 7.

NORD ACAM.5301

Under development for French Army (not yet adopted).

Command-guided anti-aircraft missile system.

NOTWITHSTANDING the adoption of the American Hawk as the standard surface-to-air missile system for the NATO nations, and the strenuous efforts being made by the sponsors of the Nike family, the R.422, Thunderbird and Bloodhound, Nord-Aviation have elected to enter the field themselves. Conversely, the fact that the ACAM.5301 is based entirely on proven principles should enable them to deliver an operational system relatively quickly and cheaply. The missile itself, the existence of which was revealed at the Paris Salon in June, is essentially a scaled-up Type 5103 employing identical aerodynamics, propulsion and guidance, a minor difference being that, like the boost charge, the sustainer motor has twin nozzles. Firing trials are in hand.

Nord ACAM.5301: length, 14ft 9in; wing span, 4ft 11in; body diameter, 13.5in; firing weight, 1,058 lb; maximum range, about 9.3 miles; flight speed, more than M 2.08.

PARCA

French Army.

Anti-aircraft weapon system for training and indoctrination.

DURING the past six years the Direction des Etudes et Fabrications d'Armement and the Compagnie Francaise Thomson-Houston have collaborated in the evolution of an anti-aircraft missile system which is now virtually fully developed. Parca has passed through many development stages, most having swept wings, but the definitive version is launched by four wrap-round boost motors, has a solid sustainer which burns for 18 sec and is controlled by a cruciform of foreplanes indexed at 45 deg to the cruciform of rectangular wings. The guidance system, known as LG/LJ, consists of an LJ pencil-beam radar, a G1 receiver and a command aerial for both, all of which are mounted on wheels. The complete system permits the airborne guidance package to be extremely simple and thus minimizes the cost of firing live rounds. Parca is currently employed for the training and indoctrination of anti-aircraft troops of the French Army.

Parca: length, 17ft 8in (slightly less without boost motors); wing span, 5ft 6.9in; body diameter, 17.72in; firing weight, 1,213 lb (2,200 lb with boost motors); maximum range, 8.7 miles; flight speed, M 1.8.

R.422

French Army (not yet adopted).

Command-guidance and terminal homing surface-to-air missile system.

FOR five years the Société Matra have been working on a weapon system for use against aircraft flying at from 26,000 to 59,000ft at speeds up to M 1.

R.422 has a cruciform of foreplanes indexed at 45 deg to a rear cruciform of large wings, and it is launched by a tandem solid boost motor. The weapon system includes the CFTH Super-Cotal radar which locks-on to the target, and the Cotal radar which tracks an Air-Equipement transponder carried by the missile. The co-ordinates of the missile and target are continuously compared by an SEA analogue computer to effect an interception. In the final phase the missile homes semi-actively on to the return radiation from the target in the wave-band 2,700 to 3,100 Mc/s. The seeker head is by SFENA, and the fragmentation-type Brandt warhead is mounted around the tube from the solid sustainer motor.

R.422-B1: length, 19ft 5.3in (30ft 7in with boost motor); wing span, 6ft 6.7in; body diameter, 15.75in; firing weight, 1,426 lb (3,527 lb with boost motor); maximum range, 31 miles; flight speed, M 2.6.

R.431

French Army.

High-performance anti-aircraft missile.

FROM the R.422 the Société Matra are developing an entirely new missile with even higher performance. It will be powered by an integral ramjet and will have a tandem solid boost motor.

RED-EYE

U.S. Army and Marine Corps.

Shoulder-fired anti-aircraft missile.

EXISTENCE of this novel weapon was announced last August 2, when the U.S. Army, U.S. Marine Corps and Convair (Pomona) disclosed plans for its joint development. It was then stated that Pomona held a development contract worth some $6m from the Army Rocket and Guided Missile Agency. Red-Eye is currently described as being "in advanced development."

Intended to provide protection for individual combat soldiers against low-flying enemy aircraft, the Red-Eye system was conceived in 1950 but was not proved technically feasible until a study contract by Convair-Pomona was completed in the summer of 1958. The missile itself is a wingless cylinder, apparently spin-stabilized, and within its slender body are housed "an electronic guidance system"—reputed to be of the infra-red seeking type—a high-explosive warhead and a two-stage solid motor. The missile is fired from a bazooka-type launcher, approximately 4ft long, 3in in diameter, which when capped at the ends serves as the shipping container.

Red-Eye: length, about 45in; diameter, about 3in; firing weight, under 20 lb; performance classified.

RSD-58

Private venture by a Swiss company.

Beam-riding anti-aircraft weapon system for mobile deployment.

LONG renowned for their armaments, Contraves AG. and the Oerlikon Machine Tool, Bührle & Co., have developed this very capable weapon system without financial assistance from the Swiss Army or Government. A full description of the system was published in our issue of January 7, 1955. Since that time it has been further refined.

Features of the missile included four delta wings indexed at 45 deg to the cruciform of tail controls, and a nitric acid/kerosine rocket (there is no booster). The motor thrust-line can be deflected to steer the missile up to burnout, after which control is exercised solely by the fins. The tactical RSD-58 has an 88-lb warhead which may be detonated by a proximity fuze or by ground command. For troop training, the RSC-57 has instead a parachute recovery system.

The complete weapon system for a battery comprises a battery command post, a radar tracker (radar for which was developed by the Belgian firm MBLE), a beam transmitter (developed in co-operation with Brown Boveri, and producing a coarse beam for gathering and a fine beam for guidance), six twin launchers, and four diesel generators. All units are fully mobile and can be brought into a state of readiness within 30 min of arriving on a site. Rate of fire of one battery can reach 12 rounds per minute. The complete weapon system has been taken up to group level by the addition of early-warning radar, a target-acquisitor radar and a group command post.

RSD-58: length, 19ft 9in; wing span, 53in; body diameter, 15.75in; firing weight, 882 lb; maximum range, 19 miles; flight speed, M 2.4.

SEACAT

Royal Navy.

Close-range, anti-aircraft defence weapon for all types of surface ship.

IN several respects Seacat falls into a category of its own. Specially intended to destroy aircraft at relatively close range (by which one may assume perhaps five miles horizontally and below 20,000ft vertically), the weapon system comprises a small and highly manœuvrable missile fired from a single or multiple launcher which can be mounted even on small ships with very confined deck space.

Like Malkara, Seacat stems from a basic configuration evolved by the R.A.E. Aerodynamic surfaces comprise four fixed tail fins indexed at 45 deg to a cruciform of acutely swept wings. The latter pivot differentially or in unison to provide control.

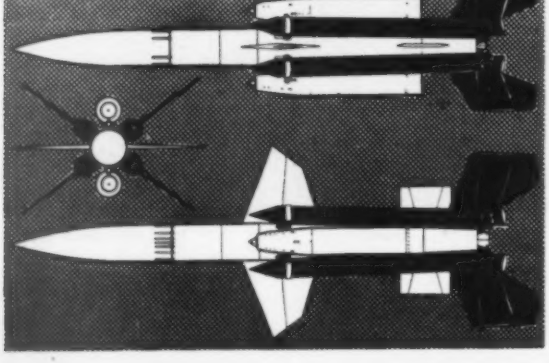
No details of Seacat's guidance system have been divulged, but it seems fairly evident that it is of a radio command nature. Supporting this contention is the fact that the fins carry mountings for tracking flares. The First Lord of the Admiralty has described the system as "a novel type of direction which gives very high promise." Propulsion is provided by a solid internal motor, doubtless comprising boost and sustainer stages.

At the recent S.B.A.C. exhibition a four-round shipborne launcher was displayed in mock-up form. Produced by Rose Bros. (Gainsborough) Ltd., the launcher is fabricated in steel, and is slewed and elevated by an electric or electro-hydraulic system, with totally enclosed geared drives lubricated by oil bath with drip feed to the gears and splash to the bearings. The control system may be linked to any suitable director sight via a data system.

Loading of the launcher is carried out at 90 deg elevation, which brings the platforms beneath the base of each missile into a horizontal position. Rounds are brought up vertically and slid into engagement with the rails on each platform, and the loaded launcher is then elevated for firing. To load the pair of rounds on the other side of the launcher the latter is slewed through 180 deg and the procedure repeated. Training and elevation stops can be provided, and these would be cut out of circuit during the loading sequence.

Short Bros. and Harland were awarded the

Bloodhound Mk 1 (same scale as missiles on pages 526-7)



Seacat development contract in April 1958. Last December the Parliamentary Secretary to the Admiralty forecast that the missile would be fitted to "a considerable number" of ships "by the early 1960s." Owing to the unique simplicity of the weapon system, and the fact that it is self-contained to an exceptional degree, Seacat has great export potential and appeals to virtually every foreign navy. The Minister of Defence for New Zealand has announced that his country's new frigates, *Otago* and *Taranaki*, will both be fitted with Seacat when they arrive in the Dominion; and the Australian Minister for the Navy recently said that it was planned to equip frigates with "short-range guided missiles." A land-based variant of Seacat is Tigercat (p. 521).

Seacat: length, 57.85in; wing span, 25.6in; body diameter, 7.5in; other data classified.

SEASLUG

Royal Navy.

Beam-riding anti-aircraft missile system for large surface ships.

DURING the past ten years the Seaslug system has been brought virtually to operational standard, and it is today proving outstandingly successful and effective. It has been developed for the Royal Navy by Sir W. G. Armstrong Whitworth Aircraft, assisted for guidance and control by G.E.C. and Sperry, respectively.

In order to minimize envelope size the missile is launched by wrap-round boost motors mounted on the forebody (so that boost fins are rendered unnecessary). At the end of the boost phase the high-impulse solid sustainer ignites, the boosts fall away, the missile is roll-stabilized and the flight-control equipment becomes operative. The latter comprises power, guidance and control packages which are mounted in 120-deg segmental compartments ahead of the cruciform of rectangular wings.

Power is provided by an iso-propyl nitrate gas-generator which drives a turbo-alternator and hydraulic pump. The guidance equipment comprises a nitrogen-pressurized receiver package and an aerial assembly which together sense the missile's positional error with respect to the centre of the pencil beam from the ship's tracking radar, while the latter is locked-on to the target. These error signals are fed to the control system, which governs the electro-hydraulic servos arranged in a ring around the motor tube and to which the four control fins are attached. Seaslug carries a large conventional warhead in a group which includes a proximity fuze and an initiator. In place of the warhead group may be fitted a telemetry head, monitoring performance through up to 48 channels.

A complete Seaslug weapon system requires some 8,000 sq ft, rendering it suitable for all ships larger than about 5,000 tons displacement. Boosted rounds may be carried in a special shock-proof container, which has already been transferred from one ship to another at sea; alternatively the weapon may be broken down into six packages, each in its own waterproof container. Rounds are moved between the magazine and the launcher on rails controlled by hydraulic handling gear. While the missile is on the move in the ship it may be kept continuously coupled to warming-up supplies and to cooling air for the electronics. After passing through automatic checkout rooms for the control and guidance systems the missile is rammed up into the launcher. The latter is a rigid steel-lattice box containing two or three rounds; it provides air and electronic connections to the missile and automatically follows the ship's radar director in azimuth and elevation.

Large numbers of Seaslugs have been fired from the R.A.E. Aberporth, from Woomera and from the trials ship, H.M.S. *Girdle Ness*. As an indication of the degree of success achieved, the following statement was issued by the manufacturer early this year: "One set of trials involved the firing of three missiles with live warheads against three jet targets. The first two missiles destroyed their targets and, in order to preserve the instrumentation in the third, the third Seaslug was deliberately programmed to miss by a predetermined distance, which it did with accuracy. On another occasion, a salvo of two missiles was fired against a single target; the first round hit and destroyed the target and the second hit the largest piece of wreckage remaining in the air." Seaslug will form the primary armament of the new "County" class of guided-weapon destroyers which are at present under construction.

Seaslug (current test vehicle): length, with or without boosts, 19ft 6in; wing span, 56.6in; body diameter, 16in; other data classified.

SUD SE.4300

Research missile sponsored by French Government.

Semi-active homing missile for research and operational deployment.

NOTWITHSTANDING its aircraft-type configuration, the SE.4300 has actually been built in some quantity and is apparently regarded as an operational weapon. Each of the four swept wings carries an elevon well outboard, and at present two of the wings carrying tracking flares at their tips. After vertical launching by a tandem solid boost unit, propulsion is provided by an acid-furaline internal sustainer. During most of its flight the weapon rides a radio beam, but terminal guidance is of the semi-active homing variety, a dish aerial being mounted in the nose. The warhead is detonated by a proximity fuze. From this missile has been evolved the SE.4400.

Sud 4300: length, 11ft 5.8in; wing span, 11ft 5.8in; firing weight, 1,323 lb (2,205 lb with boost motor); flight speed, transonic.

SUD SE.4400

Missile sponsored by French Government for eventual operational deployment.

High-performance anti-aircraft missile.

STEMMING from the SE.4300, this missile has a performance surpassing that of any other surface-to-air weapon in a comparable state of development. After vertical launching by a tandem solid boost motor cruise propulsion is provided by an internal ramjet fed with kerosine from an annular tank of 12.4 Imp. gal. Experimental rounds are being fired at Colomb-Béchar.

Sud 4400: length, 15ft 2in (23ft 7in with boost motor); wing span, about 5ft 10in; body diameter, 19in; firing weight, 770 lb (2,640 lb with boost motor); range not stated; flight speed, M 3.6 at up to 164,000ft.

TALOS

U.S. Navy; the missile is SAM-N-6.

Fully automatic dual-purpose system for installation in cruisers.

APART from the Fleet Ballistic Missile System, Talos is the most complex and expensive weapon system of any navy. Largest of the family of missiles which stemmed from the Bumblebee programme of 1946, Talos has an integral ramjet body burning kerosine and, even in its initial operational version, has a range in excess of 65 miles.

Prime contractor is Bendix Products Division, assisted by R.C.A., McDonnell Aircraft and many other companies. Two major versions are in service. One has a conventional warhead and is guided by beam-riding to the vicinity of the target, whereupon an aerial system disposed around the nose intake locks-on and provides terminal homing of semi-active variety, the target being illuminated by the very large SPG-49 shipborne radar. The other version has a subnominal nuclear warhead and can be distinguished by deletion of the semi-active homing system, together with its associated aerials and probes. Sperry and the Farnsworth Division of I.T. & T. provide the airborne guidance, which controls the missile through the cruciform of moving wings.

Although conceived for anti-aircraft purposes, Talos has payload/range characteristics which make it eminently suitable for employment in surface-to-surface bombardment rôles. The standard twin launcher is said to have a rate of fire as high as the two-per-minute maximum of the final type of U.S. Navy 16in gun, and with either type of warhead Talos is now capable of being employed with extreme accuracy against ship and shore targets. The range of "over 65 miles" refers to the anti-aircraft rôle, but should not be much curtailed by employment against surface targets. The shipboard installation required to support Talos fills a substantial proportion of the hull of a 14,000-ton cruiser. Some 100 rounds are stored in the magazine with their tandem boosters attached. An automatic system tied in with the fire-control selects a particular round and has it brought up to the launcher via fuzing and check-out rooms. A live round with its shockproof handling gear and tray weighs 32,000 lb, and the GE electric lift which hoists the missile to deck level weighs 350 tons.

The first Talos ship was CLG-3 *Galveston*, which was commissioned on May 28 last year and fired the first operational Talos at sea last February 24. By the spring of 1962 seven cruisers will be operational with Talos as their main armament, and one ship—the revolutionary nuclear-powered *Long Beach*—will have no guns at all. At one time both the U.S. Army and Air Force studied a land-based Talos system, but its extreme cost and complexity have caused these studies to be abandoned. Work is currently in hand upon the extension of the missile's range to 100 miles, and persistent unofficial reports speak of a projected Super Talos which, although embracing much of the existing weapon system, would include a completely new missile with anti-ICBM capability.

SAM-N-6 Talos: length, about 20ft 6in (30ft 6in with boost motor); wing span, 112in; body diameter, 30in; firing weight, 3,100 lb (7,000 lb with boost motor); maximum range, over 65 miles; flight speed, M 2.5.

TARTAR

U.S. Navy.

Anti-aircraft missile for destroyers and all larger classes of surface ship.

SMALLEST of the missiles stemming from the original Bumblebee programme by the Applied Physics Laboratory of Johns Hopkins University, Tartar has been evolved from the earlier members of the family jointly by this laboratory and Convair. In effect an Advanced Terrier (p. 524) without the latter's separate booster, and likewise produced by Convair at the Naval Industrial Reserve Ordnance Plant at Pomona, Cal., Tartar is designed for use in primary batteries aboard destroyers and similar vessels as well as in secondary batteries aboard larger ships.

Compared with the original Terrier, Tartar achieves comparable range with a warhead of similar weight in a missile whose overall envelope size approximates to that of the basic Terrier without its tandem boost motor. Thus a given size of magazine can hold roughly twice as many Tartars as Terriers. The airframe has been completely refined and cleaned up (see Advanced Terrier), and "the use of miniaturization techniques was required to pack the sophisticated guidance, propulsion and construction systems" into so small a package. According to an unofficial report beam-rider guidance is employed, although there are indications that semi-active homing is used in the terminal phase. Propulsion is provided by an Aerojet-General solid-propellant motor comprising boost and sustainer charges. A proximity fuze system detonates the conventional warhead.

Tartar is in pilot production at Pomona, under a $8m contract from the BuOrd, and intensive testing is in progress both at the Naval Ordnance Test Station at China Lake, Cal., and aboard U.S.S. *Norton Sound*. A production contract valued at some $35m has now been placed, and the operational Tartar will join the Fleet late next year as the primary defensive weapon of a new class of 18 destroyers ordered in the 1957 shipbuilding programme. It will also form the secondary armament of the heavy cruisers *Chicago*, *Albany* and *Fall River*.

Tartar: length, about 15ft; wing span, about 20in (fin span, 3ft 5in); firing weight, about 1,500 lb; maximum range, 10 miles; flight speed, over M 2.5.

TERRIER

U.S. Navy and Marine Corps (and possibly to be employed by the navies of Japan and certain NATO nations); the missile is SAM-N-7.

Beam-riding anti-aircraft missile for operation from cruisers, destroyers and beachhead launchers.

HISTORY and details of this long-established weapon system were contained in our 1957 Missiles issue (December 6). The result of eight years of research and development by the Applied Physics Laboratory of the Johns Hopkins University, it was the first return from the Bumblebee programme which has also led to Talos and Tartar. The missile itself is quite small and has cruciforms of moving wings and fixed fins indexed in line. A solid sustainer motor is fitted and the missile is launched by a large tandem boost motor.

Several thousand rounds have now been

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delivered by the prime contractor, Convair, from the Naval Industrial Reserve Ordnance plant at Pomona, Cal. Currently in commission are two cruisers, *Boston* and *Canberra*, and the destroyer *Gyatt*. The latter has a single twin-launcher on its quarterdeck, and the cruisers each have a pair of such launchers fed automatically from a pair of magazines. Under current shipbuilding programmes Terrier will be deployed aboard three carriers, four cruisers and 20 frigates. Terrier is also in service with the U.S. Marine Corps to protect ground battalions during beachhead operations. Under development is the Advanced Terrier (p. 524).

SAM-N-7 Terrier: length, 14ft 9in (26ft 5in with boost motor); wing span, 3ft 10in; body diameter, 13in; firing weight, 1,100 lb (2,900 lb with boost motor); maximum range, 10 miles; flight speed, M 2.5.

THUNDERBIRD

British Army and (evaluation) Royal Air Force; the weapon system bears the code name of Red Shoes.

Semi-active homing surface-to-air missile for mobile or fixed units.

A COMPREHENSIVE account of the inception and development of the entire Thunderbird weapon system was published in our issue of September 25. The account emphasized the manner in which the entire weapon system has been engineered (in many cases by complete mechanical redesign) to fit it for arduous duty with army units in all parts of the world. To the maximum possible degree maintenance is effected by immediate replacement of the defective parts, and English Electric Aviation, the prime contractors, have gone to great lengths to minimize the demands which the system makes upon its operators, its supply logistics and the need for personnel with special skills.

The basic missile has a typically British configuration, with cruciforms of large wings and rear control fins indexed in line, and four wrap-around boost motors carried on the aft-body. From front to rear the body comprises: an ogival, pointed nose of dielectric material serving as a radome for the receiver aerial dish; the dish itself, carried on a gyro-stabilized homing head; a guidance bay; the warhead bay; the large solid-propellant sustainer motor, around which are mounted the four wings; the control system and auxiliary power unit, disposed around the motor tube; the control ring carrying the four fins nozzle.

On arrival at its destination the missile is assembled in a Field Assembly and Test Point, and subjected to sequential go/no-go checks to ensure the serviceability of every portion. When fully cleared the missile is completed by the addition of its warhead and boost motors, following which it is mounted on a launcher-elevating frame which is then mounted upon a launcher base.

Completing the weapon system are a tactical radar, tracking and illuminating radar, radar display vehicle, generator, sensitivity test vehicle, battery control post and launch control post. All these items are mounted on standard army vehicle chassis, and even the launcher base may be mounted on wheels which are removed only when the firing site has been selected. In practice it is probable that the user battalion would be permanently based at a given site for a period of many months, except in a war of movement on the ground. Nevertheless, the entire system has been planned to operate independently of local support and without any permanent fixed installation.

Several hundred rounds have been fired at Aberporth and Woomera, and the entire weapon system is now virtually fully developed and in Army hands. In September 1957 the Air Ministry announced that an evaluation order had been placed by the Royal Air Force, possibly for deployment overseas by the R.A.F. Regiment. In the event, although the R.A.F. are continuing their study of the weapon system, this is being done by analyzing the results obtained by the Army. The latter are at present equipping two Regiments with Thunderbird Mk 1, the first unit being 36 GW. Regiment (A.A.), R.A. In addition a complete training school for the weapon system is maintained at Manorbier, Pembs (*Flight*, June 5, 1959).

Owing to its modular character it has always been evident that the Thunderbird weapon system could be progressively extended in performance merely by removing limiting components and replacing them with new ones. That this is in fact being done is indicated by the announcement, made earlier this year, that a Mk 2 version of Thunderbird is well advanced in development.

Thunderbird Mk 2 is claimed to offer substantial advances in range and overall lethality and to be better suited to engaging targets at all altitudes. It has frequently happened in the past that missiles with semi-active homing guidance have been limited electronically, in that the effective range of the radars has been less than the practicable range of the missile up to the point at which the flight speed becomes too low for control to be maintained. Although all details are obviously classified it seems fair to assume that the electronic performance of Thunderbird Mk 2 must be considerably better than that of the Mk 1 system.

Thunderbird Mk 1: length, with or without boost motors, 21ft; wing span, 5ft 3in; body diameter, 21in; firing weight, probably about 2,200 lb (over 4,000 lb with boost motors); maximum range, probably over 20 miles; flight speed, probably over M 2.

WIZARD

Advanced Research Projects Agency.

Study for anti-missile system.

FOR more than four years the U.S. Air Force has been investigating an anti-ICBM system under the project name of Wizard. Originally it was anticipated it would lead to hardware but, as noted in our 1958 review, this is now very unlikely. ARPA placed two contracts totalling more than $25m with Convair, and the latter company are maintaining a scientific team at San Diego on this programme.

AIR TO AIR

AA.20

French Air Force, French Navy, Luftwaffe (W. Germany) and possibly other NATO countries.

Command guided air-to-air or air-to-surface missile.

PRODUCED by Nord-Aviation as the Type 5103, this missile is now in bulk production and total deliveries must exceed 1,000. The complete weapon system includes a minimum of fighter-borne equipment (twin launchers, control stick, signal generator and transmitter weigh some 120 lb), and owing to its rudimentary nature it can readily be employed in both air-to-air and air-to-surface rôles within certain limitations. Propulsion is effected by a two-stage solid motor and control is achieved by vibrating jet-deflectors which impart a continuously varying degree of asymmetry to the thrust axis. From the moment of launching the missile may be controlled by radio signals from a miniature joystick in the cockpit of the parent aircraft, moved by the pilot to keep the missile's tracking flares always aligned with the target. Thus the system can be operated only when the target can be clearly seen by the pilot of the launching aircraft. Nord state "guidance can also be obtained by an automatic remote-control system."

The weapon has been operational with the Armée de l'Air for some two years. Following simulator training and S.S.11 firings from Magisters, pilots of Mystères are classed as proficient after firing two live A.A.20s. The missile is also standard equipment with Aquilon Squadrons of the Aéronavale, and all Fiat G.91 light ground-attack aircraft of the Luftwaffe are equipped to carry two of these weapons in the air-to-surface rôle.

Nord A.A.20 (Type 5103): length, 8ft 6.4in; wing span, 31.5in; body diameter, 9.84in firing weight, 296 lb (in air-to-surface role, 317 lb); maximum range, 2.5 miles; flight speed, M 1.7.

C-7

Italian Air Force.

IR-homing air-to-air missile.

FOR several years SISPRE (Societa Italiana Sviluppo Propulsione a Reazione, formed jointly by Fiat and Finmeccanica) has held contracts from the Italian Air Force for the development of an air-to-air missile employing infra-red homing. The company have aimed at producing a simple, functional, practical and reliable weapon, which can be manufactured with a minimum outlay on tooling, and which necessitates little aircraft-conversion and few skilled personnel.

An unusual feature of the missile is that it manœuvres by twist-and-steer. It has a cruciform of fixed tail fins and a pair of wings of trapezoidal section, often fitted with end-plates, each wing being hydraulically actuated to move the missile first in roll and then in pitch. Propulsion is effected by a solid-propellant motor, and the warhead is exceptionally large in relation to the overall size of the missile. An infra-red seeker is mounted behind the glass nose, and the company state that its detection range is "extremely high" and that "big angular errors in firing are tolerated." They go on to say that the "development stage" is to be completed during the early part of next year, and that series production will begin in 1961.

C-7: length, 6ft 5in; wing span, 25in; body diameter, 6.3in; firing weight with 55 lb warhead, 143 lb; maximum range, 6.2 miles; flight speed, M 1.9.

EAGLE

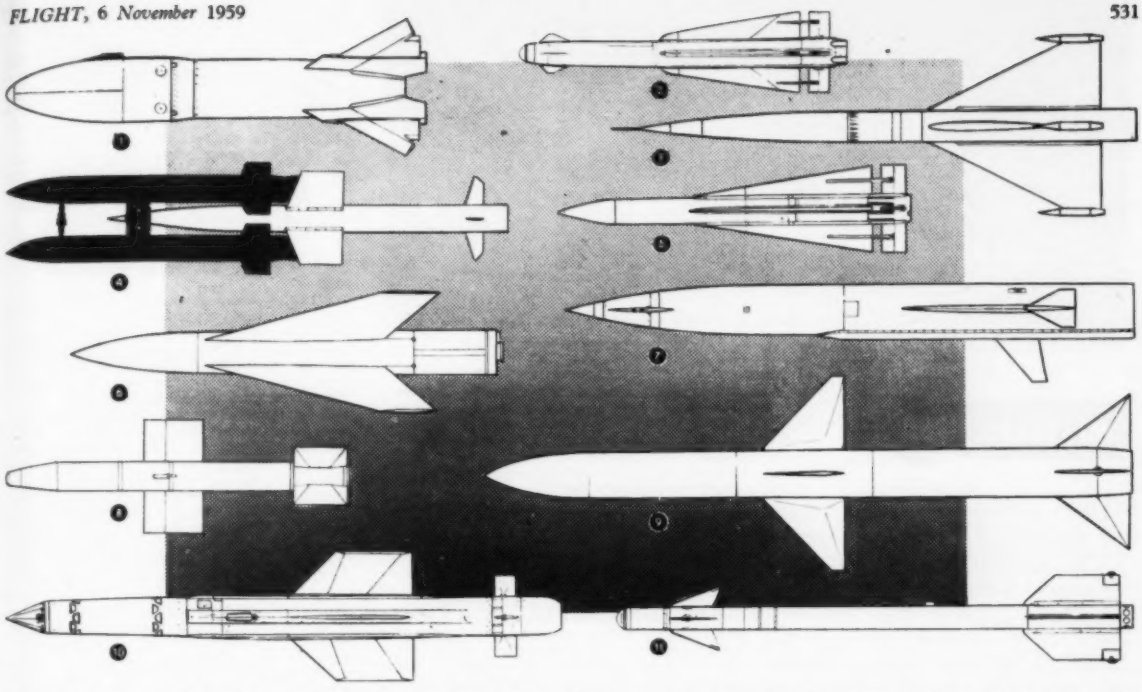
U.S. Navy; the missile is AAM-N-10.

Long-range high-performance air-to-air missile.

WITH this missile the U.S. Navy are investigating the practicability of an entirely new concept in which all the performance required to intercept and kill an enemy aeroplane is built into an air-to-air missile and not into its carrier aircraft. The latter will be a new design of aeroplane, probably powered by a pair of turbofan engines and housing a pilot and navigator and a huge amount of target-tracking radar, fire-control and countermeasures equipment. It would be designed for operation from all types of carrier, and under the project name of Missileer a competition for its design has reached an advanced stage.

Eagle would be its only armament, and the aircraft would serve solely as a launching platform for this missile. Few details of Eagle have been divulged. Prime contractor is Bendix Systems Division, at Ann Arbor, Michigan. They have in turn assigned a number of firms to be their chief sub-contractors. Grumman will handle complete responsibility for the airframe and propulsion system, and will develop the launching system and some of the ground handling equipment. In turn Aerojet-General were awarded an $8m sub-contract from Grumman in October for a "high-performance propulsion unit."

Guidance and control are unofficially said to represent 75 per cent of the total cost of Eagle, the airframe and the propulsion system respectively accounting for but 15 and 10 per cent. A fully active radar system to be carried by Eagle is being developed by the Air Arm Division of Westinghouse. Electronic guidance equipment is coming from the Research Laboratories Division of Bendix at Detroit. Sanders Associates will design the seeker, and an unofficial report states that this terminal-homing device will take the form of a coherent-pulse Doppler radar of very high resolution. Litton Industries will provide "a computer, to maintain the maximum effectiveness of the system." Eagle will carry a nuclear warhead. Bendix-Pacific "will design and produce subassemblies and will perform missile assembly and test." Ultimately the Missileer aircraft



Drawn to a common scale against a tinted panel representing a width of 15ft are: 1, Genie; 2, GAR-2A Falcon; 3, Robot 321A; 4, Fireflash; 5, GAR-3 Falcon; 6, A.A.20; 7, R.511; 8, C-7 (plan view); 9, Sparrow 3; 10, Firestreak; and 11, Sidewinder 1A

will carry Westinghouse fire-control radar, but in the meantime the equipment will be the ATQ-75 produced by the Autonetics Division of N.A.A. (the same fire-control is in the F4H Phantom 2).

One report states that the planned expenditure on Eagle is $7m for the first year (presumably FY59) and in succeeding years $8m, $10m, $14m and $60m (the latter including the first production deliveries). Evaluation and testing of experimental vehicles for this programme is likely to start shortly at the NAMTC at Point Mugu. One unofficial report links the progress of the Eagle with that of the British Red Top (p. 532).

XAAM-N-10 Eagle: length, probably over 15ft; firing weight, probably over 2,000 lb; design range, between 30 and 100 miles; flight speed, over M 3.

FALCON

U.S. Air Force; the missile is GAR-1, -2, -3 or -4.

Small air-to-air missile with semi-active radar or IR homing.

AS the standard guided missile of most types of American intercepter, Falcon has been manufactured by Hughes Aircraft in Tucson, Arizona, since 1953, and total deliveries must now exceed 15,000 rounds. A history and description of the Falcon family was published in our 1957 Missiles issue.

Production of the GAR-1 (semi-active radar) and GAR-2 (infra-red) is complete. The former went into squadron service in March 1956 and the latter was cleared for use the following year. Both types are now in wide inventory use with squadrons equipped with the F-89J and K, the F-101B, the F-102A and the F-106.

Like the two original versions, the current GAR-3 and GAR-4 consist of a cylindrical body carrying a cruciform of highly swept wings with trailing edge controls carried on outriggers. Propulsion is provided by a Thiokol solid motor. In the GAR-3 and -4 a longer propellant charge gives greater thrust and longer burning time; and other improvements include a new airframe and a much enhanced guidance system.

GAR-3 is the current radar Falcon, and it is matched to the new Hughes fire-control systems currently in service, such as MA-1. The -4 is the heat-homer. Both types are now in full production and they entered service with an F-106 squadron at McGuire A.F.B. last July. Commonly known as the Super Falcon, the GAR-3 and -4 are both normally carried in a mixed load and fired in pairs. Last July the Air Materiel Command Aeronautical Systems Center moved management of the GAR weapon systems to the procurement offices of the launching aircraft, so that the present management arrangement is as follows: F-101B, GAR-1D, GAR-2A and MG-13; F-102, GAR-11 (a variation on the -3/4) and MG-10; F-106A, GAR-3A, GAR-4A and MA-1.

GAR-1, GAR-2 Falcon: length, 6ft 5.8in; wing span, 20in; body diameter, 6.5in; firing weight, 110 lb (GAR-1) or 122 lb (GAR-2); maximum range, 5 miles; flight speed, over M 2.

GAR-3, GAR-4 Super Falcon length, 7ft 1.5in; wing span, 26in; body diameter, 6.5in; firing weight, about 150 lb; maximum range, more than 5 miles; flight speed, over M 2.5.

FIREFLASH

Royal Air Force (No. 1 GWDS).

Beam-riding air-to-air missile.

A DETAILED account of the Fireflash—originally code-named Blue Sky—was published in our issue of August 16, 1957. It was the first British guided weapon to see operational service, having been used in an indoctrination rôle for some two years by No. 1 Guided Weapon Development Squadron who operate Swift F.7 aircraft from Valley, Anglesey. Developed and manufactured by Fairey Aviation, Fireflash was produced as an interim weapon pending the availability of Firestreak. An unusual feature is that after acceleration to supersonic speed by upper and lower boost motors the latter are jettisoned, leaving an unpowered dart with optimum properties as a receiver of coded transmissions from the rear (the pencil radar beam, which it rides to intercept its target).

Fireflash: length, 7ft 5in (9ft 3.75in with boost motors); wing span, 28.1in; body diameter, 5.5in; firing weight, 300 lb; maximum range, several miles; flight speed, over M 2.

FIRESTREAK

Royal Air Force (Fighter Command) and Royal Navy.

IR-homing air-to-air missile.

SINCE the end of 1951 this missile has been under development by de Havilland Propellers Ltd., originally under the code-name of Blue Jay. A history of its early development was published in our issue of May 3, 1957.

Most of the circular-section body is built up from high-strength light alloy. The pointed nose is formed from eight optically flat panels of heat-resistant glass which offer minimum obstruction and refraction to the incoming infra-red (heat) radiation emitted by the target. This radiation is gathered in a mirror system, geometrically similar to an astronomical telescope, which concentrates it upon a sensitive cell. The cell and mirror system form a homing seeker head which can be locked-on to the target before the missile leaves its parent aircraft. The complete homing-head is stabilized by a gyro system, and its function is to determine the rate of change of the sight-line to the target and, according to a proportional-navigation law, pass a demand signal to the missile's control system for the required acceleration towards the target.

This signal is passed to the electronics package, which occupies some 4in of the forebody, which in turn feeds a suitably processed signal to the control actuators. The latter, fed at 300 lb/sq in by air stored at much high pressure in a toroidal bottle around the motor tube, comprises four push/pull rams disposed ahead of the wings and driving the tail controls through externally faired rods. The resulting missile acceleration is then sensed by the electronics package and compared with that demanded. Propulsion is effected by a solid-propellant internal motor, and the large conventional warhead is detonated by a proximity fuzing system which senses the target bearing through rows of windows around the forebody.

Many hundreds of test firings have now taken place, and Firestreak has been shown to have an outstanding performance. The homing system is said to "possess qualities of great range and sensitivity," and to permit aircraft to be engaged from anywhere in the rear hemisphere. Radiation from the Sun and cloud background is said to have little effect "and countermeasures are unlikely to be effective." Basic design and development was handled at the Propeller Company's engineering base at Hatfield, and flight-testing was done principally by the Joint Services Trials Unit at Woomera. The missile is now in quantity production in the prime contractor's northern group of factories—Lostock, Walkden, Farnworth and Lakefield—for squadrons equipped with the Sea Vixen and Javelin (and, later, the Lightning). Equipment carried by the parent aircraft is packaged into a power unit, slaving unit (not always needed) and launch-sequence unit, which may be housed in an external belly pod in machines not originally designed to carry it.

Firestreak Mk 1: length, 10ft 5.3in; wing span, 29.4in; body diameter, 8.67in; weight, probably about 300 lb; maximum range, at least 4 miles; flight speed, over M 2.

Sparrow 3 fired from F3H-2M Demon

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GAR-9

U.S. Air Force.

Advanced air-to-air missile.

STEMMING from the earlier Falcon family, GAR-9 is an entirely new missile which was matched to the requirements of the now defunct F-108 Rapier interceptor. In this aircraft it would have been linked with the ASG-18 fire-control equipment. Although smaller than the Navy's Eagle (*q.v.*) GAR-9 will carry a nuclear warhead and should have a range of at least 10 miles. In view of the cancellation of the F-108 the funding for GAR-9 has been substantially reduced, but work on it is being continued "for possible application in other weapon systems."

GENIE

U.S. Air Force; the missile is MB-1.

Unguided air-to-air missile with nuclear warhead.

ALTHOUGH not significantly larger than most other air-to-air missiles, Genie carries a nuclear warhead and accordingly is able to dispense with a guidance system. Instead it is corrected against gravity-drop by a simple stabilization system employing four flick-out fins. The missile has been under development for some six years and is now in full production by the prime contractor, Douglas Aircraft.

In most types of Genie so far manufactured the warhead is a sub-nominal device with a yield unofficially placed at 1.5 KT. Propulsion is provided by an Aerojet-General solid motor.

Genie is carried by the Northrop F-89J, the McDonnell F-101B and the Convair F-106; and it is unofficially reported that it may be carried by the F-104 and the British Lightning. In its current applications the launching aircraft is homed on to its target by Hughes MG-12, 13 or MA-1 fire control and the missile is fired about 7,000ft range, initially curving downwards to prevent the rocket flame from entering the turbojet intakes. Detonation of the warhead is accomplished by a proximity fuze. A large number of Genies are now in inventory service with the Air Defense Command, some being MB-1T training rounds (non-nuclear). Cost of the basic missile is only $7,000 but the warhead system accounts for $250,000.

MB-1 Genie: length, about 8ft; body diameter (warhead), 15in; firing weight, approximately 900 lb; optimum range, said to be 1.5 miles; flight speed, M 4.

R.511

French Air Force.

Semi-active radar homing air-to-air missile.

SINCE 1951 the Société Matra have been actively developing an unusual family of air-to-air weapons which manœuvre by twist-and-steer. The cylindrical body has a wing at the rear (sometimes fitted with small fins) together with moving foreplanes and a ventral rudder. Propulsion is provided by a Hotchkiss-Brandt solid motor giving 3,530 lb thrust for 3 sec, and thereafter providing 441 lb thrust for 13.5 sec. Auxiliary power is provided by an Andyar silver/zinc battery, which drives the control servos and gyro accelerometer.

The parent aircraft's fire-control illuminates the target, and the return emission is homed upon by a seeking aerial in the nose of the missile, offset 8 deg from the major axis and scanning conically at 225 revolutions per second. For long-range firing, an aerial in the trailing edge of the missile's wing receives the coded transmission directly.

An IR homing head was developed with approximately the same weight and bulk. It scans over 20 deg and during test firings at Colomb-Béchar proved extremely accurate, but the PbS sensitive element could only be used at night and this system has been abandoned.

R.511 is now in full production. The operational round has a Hotchkiss-Brandt h.e. warhead, can be fired from any point from 30 to 60 deg from the axis behind the target, and can pull 12g at M 1 at 33,000ft altitude. It is operationally deployed with Vautour squadrons, each aircraft carrying four rounds on wing pylons. The missile is also being further developed for the Mirage III.

R.511: length, 10ft 2in; wing span, 39.37in; body diameter, 10.24in; firing weight, 397 lb; maximum range, 4.35 miles; flight speed, M 1.8.

RED TOP

Presumably Royal Air Force and Royal Navy.

Advanced IR-homing air-to-air missile.

IT has been known for more than a year that an advanced successor to Firestreak is being developed. De Havilland Propellers have said, "The team responsible for the development of Firestreak has unrivalled experience in the field of air-to-air guided missiles, and especially in proximity fuze and infra-red guidance techniques. This experience is now being applied to the development of more advanced air-to-air missiles with the improved performance needed to keep abreast of increases in target speed and operating altitude."

According to our American contemporary, *Aviation Daily*, the code name of this advanced missile is Red Top. The publication goes on to say, "Navy's Eagle air-to-air missile program may receive a dividend from flight tests of England's air-to-air Red Top missile in the form of an exchange of technology. The information may lead to earlier availability of the Eagle, U.S. observers at the Farnborough air show report. The Red Top, being developed by de Havilland Propellers, is said to carry a 68-lb non-nuclear warhead over a range of 14,000yd. It may be an advanced version of the Firestreak. Red Top would be carried by the de Havilland Sea Vixen. It has infra-red guidance using a cooled lead telluride cell receiving in a 4-to-5 micro range."

ROBOT 321

Royal Swedish Air Board.

Test vehicle for air-to-air missile.

BRIEF details and a drawing of Robot 321A were given in our 1958 Missiles issue. It is a ground-launched vehicle which will lead to an air-to-air weapon for the J-32C Draken.

SIDEWINDER

U.S. Navy, U.S. Air Force, U.S. Marine Corps and Air Forces of Australia, Norway, Japan, Sweden, Spain, Nationalist China and the Royal Canadian Navy (and, shortly, at least six other NATO countries): the missile is AAM-N-7 (U.S.N.) or GAR-8 (U.S.A.F.).

Simple infra-red homing air-to-air missile.

AS a result of its unusual simplicity, low first-cost and ready adaptability to any modern fighter, Sidewinder is the most widely used guided weapon in the world, and it appears to have largely cornered the market for this category of missile. It suffers from severe shortcomings, including a limitation of firing angle when pointing in the direction of the Sun, inability to intercept targets except from astern, rather lower powers of manoeuvre than certain other air-to-air weapons and a relatively small warhead. But the fact remains that it has been chosen by such "uncommitted" countries as Australia and Sweden after the most careful evaluation. During the Quemoy crisis in September 1958, Sidewinder became the first guided weapon to destroy aircraft in combat.

A history was published in our 1957 Missiles issue (December 6). After being conceived at the Naval Ordnance Test Station at China Lake, Cal., Sidewinder was developed jointly by that establishment and Philco's Government Industrial Division. In 1957 General Electric became an additional prime.

A Sidewinder consists of sections of light-alloy tube which contain (front to rear) a miniature heat-seeker system behind a hemispherical glass nose; the packaged control unit, which moves the cruciform nose fins; distributed warheads wrapped in optimum fragments; a 75in solid-propellant motor; and a cruciform of fixed tail fins, in the tips of which are stabilizing flywheels driven by slipstream.

All Sidewinders currently in service are of the SW-1A model. An unofficial report states that 6,000 of this type are currently to be made in Europe, and that 5,000 of these will be produced by Bodenseewerk Perkin-Elmer. Now in an advanced state of development is the SW-1C. Described as "an advanced second-generation missile" the 1C has higher speed and greater range, and an improved guidance system which greatly increases its operational flexibility.

AAM-N-7 Sidewinder 1A: length, 9ft 5in; fin span, 20in; body diameter, 4.8in; firing weight, 155 lb; maximum range, 2 miles (more in favourable conditions); flight speed, M 2.5.

SPARROW

U.S. Navy and Marine Corps: Sparrow 1 is AAM-N-2 and Sparrow 3 is AAM-N-6.

Air-to-air missile system for use by carrier-based aircraft.

ORIGINALLY conceived as Project Hot Shot immediately after World War 2, Sparrow 1 was developed for the Navy Bureau of Aeronautics by the Sperry Gyroscope Co., and some 2,000 rounds were delivered from the Sperry-Farragut Plant between 1951 and 1957. A full history of Sparrow 1 was contained in our 1957 Missiles issue. It was a beam-rider.

Sparrow 2 was evolved by Douglas Aircraft in 1955, but was cancelled when its carrier—the XF5D—was also terminated. For a long period Sparrow 2 was the missile chosen by the R.C.A.F. to be made in Canada for the Arrow 2 intercepter, but this programme has now been abandoned. Sparrow 2's airframe, however, served as a basis for the Sparrow 3, which from 1954 onwards has been the prime responsibility of Raytheon.

Compared with Sparrow 1, Sparrow 3 has approximately the same envelope dimensions but has a larger body, greater wing area and enormously increased lethality. In part the improvement stems from its new guidance system, which is of the semi-active radar homing variety. The parent aircraft illuminates the target in a pencil radar beam (the aircraft itself does not have to be aimed at the target), and the coded reflection is picked up by a seeker aerial in the nose of the missile. Sparrow 3 has been shown to have true all-weather capability and to be capable of intercepting its target "from all aspects, including head-on." Propulsion was originally by a solid motor, but current production has one of the Guardian series of packaged liquid-propellant engines by Reaction Motors.

Sparrow 3 became operational in August 1958, and several F3H-2M Demon squadrons are now cleared to use it. An advanced version of Sparrow 3, described as having "higher capability," is being developed for the F4H-1 Phantom 2 intercepter, which will carry four of these missiles beneath the fuselage.

AAM-N-6 Sparrow 3: length, 12ft; wing span, 39in; body diameter, 9in; firing weight, 380 lb; maximum range, over 5 miles; flight speed, over 1,500 m.p.h. (M 2.3).